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S. P. E. E. ITEMS OF INTEREST

1937 Meeting

The dates of the 45th annual meeting of the Society for the Promotion of Engineering Education have been changed to **June 28** to **July 2** inclusive. This change was necessary in order that we might have the use of the dormitories at Harvard University; also Harvard's Commencement comes the preceding week.

President Hammond, with the approval of the Program Committee, has selected "The Teacher—A Human Being" as the theme for the 1937 meeting. The Program Committee is at work and expects to be able to issue the program, in skeleton form, about March 1. Local committees are being formed and the personnel will be announced shortly.

With our meeting scheduled for June 28 to July 2, the American Institute of Electrical Engineers meeting in Milwaukee, June 21–28; and the American Society of Mechanical Engineers meeting in Detroit, May 17th, many members can plan to attend our meeting at Cambridge as well as the professional meeting in which they are also interested. Unfortunately we do conflict with the meeting of the American Society of Testing Materials which is being held in New York City June 28 to July 2.

Committees

C. C. Williams, Lehigh University, has been appointed Chairman of the Committee on Relations with Other Engineering Societies. This committee acts in an advisory capacity to the Council of the Society in recommending the place of the annual meetings. Council has authorized the policy of fixing the meetings two years in advance so as to avoid undesirable conflicts with conventions of other engineering societies, and also in so far as practicable to have our conventions come in sections of the country which would make it convenient for our members to attend one of the national conventions also. (See page 456, this issue.)

R. A. Seaton, Kansas State College, has been appointed one of our three representatives on the Engineers' Council for Professional Development—H. P. Hammond, Chairman, and D. C. Jackson.

F. A. Magoun, Massachusetts Institute of Technology, and O. W. Eshbach, American Telephone and Telegraph Company, have been appointed members of the Committee on Professional Status

and Employment of Engineering Graduates—John R. Bangs, Jr., Chairman.

H. H. Remmers, Purdue University, has been appointed a member of the Committee on Comprehensive Examinations—C. V. Mann, Chairman.

Membership

119 new members have been added to the roll of the Society since July 1, 1936. We have lost 16 members by death and 41 by resignation.

The February number of The Journal of Engineering Education will be the Year Book of the Society. We are anxious to include in this the names of as many new members as possible. Will you, therefore, assist the Membership Committee by having one of your colleagues fill out the application blank on the back of this Journal, secure the necessary sponsors, and mail it at once to the secretary, F. L. Bisop, University of Pittsburgh, Pittsburgh, Pa.

Dues

Approximately one-half of the members have paid their 1936–37 dues which are payable in advance July 1, 1936. The discount period expires in January. Send in your check at once.

ENGINEERING EDUCATION AT CAMBRIDGE UNIVERSITY, ENGLAND *

By J. N. GOODIER,

Ontario Research Foundation, Toronto, Ontario

While we are yet unfamiliar with any but the system of education we have been through ourselves, we are apt to take it for granted that that is how things should be. When we observe another system from the standpoint of our own, we do so of course inevitably with some inbred prejudice, but we observe also against a background of those ideal features we believe should be common to both. It seems to me, therefore, that the discussion of these ideals is important in such a symposium as this. So let us first spend a few moments on ideals of engineering education in universities. Then I will attempt to describe how these ideals are sought at Cambridge. I have also been assured that there is some interest in the influence of the Cambridge schools of mathematics and physics on the engineering teaching.

The aims of engineering education in the universities are, or shall we say, should be, twofold. In the first place there are obvious technical requirements in that the student must accumulate that knowledge which is basic in his profession. In the second place there is the more subtle requirement that the engineer be so trained that he will not be narrowed and handicapped in playing his part as a responsible member of society as a whole.

As to his technical training, the great question is, of course, how to strike the due balance between time-absorbing training in scientific laws and principles, and the urgencies of narrowly specialized professional, or even vocational, training which will give him more immediate economic value. And are the students to divide themselves into civil, electrical, mechanical, or chemical engineers as soon as their university education begins, or are their decisions better deferred until they are more conversant with the principles underlying all the major branches of the profession?

What answer is made must depend very largely, of course, on economic and other external conditions. A thorough training in mathematics and physical science is plainly at the time a somewhat expensive luxury, whether or not it brings to the individual greater

* Paper read at meeting of New England Section, S. P. E. E., Burlington, Vt., Oct. 10, 1936.

benefit in the long run. Such universities as Manchester or Birmingham, with great industries all around them, have each their local services to perform, and their situation is quite different from that of Oxford or Cambridge, whose service is not local but national, and can be based on a longer view.

The view on which the Cambridge system is based is that a scientific engineering education, free from any technical specialization at all, not only equips the student with principles capable of wide application, but endows him with an attitude of development rather than mere maintenance, towards himself as well as his profession, and directs him to think for himself about each problem he encounters, rather than be content with what he can deal by formula and strict precedent. It is believed, and also held that experience shows, that such a student will be ready to advance himself in whatever branch of the profession he may then find his place, and, other things being equal, will outstrip his less fortunate colleague equipped with more practical but less truly educational training.

As you will see, this puts the onus on the student rather than on the teacher, and you will be able to compare it in this respect with the systems of this country.

Let us now look at the curriculum of the honors course. As soon as the student enters the university, he faces a qualifying examination in mathematics, statics, and dynamics. This covers the use of the slide rule, the exponential theorem and logarithms, the solution of triangles, elementary vector analysis, the simple properties of conic sections; applications of the differential and integral calculus to maxima and minima, areas and volumes, plane curves, and the expansions of simple functions; force diagrams for simple frames, friction, the graphical representation of particle motion, the dynamical laws, and problems of dynamics as far as the rotation and oscillation of rigid bodies about fixed axes. The student who has been well grounded in mathematics and mechanics at his school will pass this examination immediately. Others may delay it for more than a year. The first year is then spent either wholly on the first year course of the department of mathematics, the subsequent examination being part I of the "Mathematical Tripos," or else on the first year work of the engineering school. The former includes pure geometry with reciprocation and inversion, algebra, trigonometry, of course to a much higher analytical standard than the qualifying examination, analytical geometry as far as the ellipsoid, the calculus with simple linear differential equations, dynamics including orbits under central forces, statics of liquids and gases, elementary electricity and magnetism, and optics including elementary wave theory. The questions set on these physical sub-

jects are intended to test knowledge of the physical phenomena, not merely analytical developments, and there is complete freedom of method.

On the other hand those freshmen who choose to begin their work at once in the engineering department take courses in mathematics and mechanics, mechanics of machines and hydraulics, heat and heat engines, electricity, shop practice, and drawing.

At the beginning of the second year, these two groups merge. The second year work is in mathematics, especially differential equations, mechanics, strength of materials, theory of structures, heat and heat engines, applied electricity, drawing (especially the graphic solution of problems), laboratory work in testing materials, metallurgy, hydraulics, engines and boilers, and electrical machinery and testing; and this continues into the third year. Although an examination is held at the end of the second year, it is not required for the degree. It serves mainly for the guidance of students and tutors, for it is necessary to decide by the beginning of the third and final year whether or not the student will attempt any of the optional more advanced and more specialized work, on which questions are set in part B of the Tripos, or final, examination. To be placed in the first class, a student must do well in two of the subjects, or well in one and fairly well in two others. The questions are very mathematical for the most part, comparable in standard, where the subjects correspond, with those of the advanced part of the Mathematical Tripos. Coming as they do in the undergraduate courses, they give the able student his opportunity to "go all out" and show what he can do. The subjects are applied mechanics, mechanics of machines, theory of structures, heat and heat engines, electric power, electric signalling, and aeronautics.

Naturally a large group of the students is content with part A, the more elementary part, on which second and third class degrees are given. The examination must be taken as a whole, before the end of the fourth year. It is usually taken at the end of the third year, and only one attempt is allowed. No fourth year courses are given.

The papers of part A are on applied mechanics, mechanics of machines and hydraulics, theory of structures, heat and heat engines, applied electricity, chemical and physical properties of materials, drawing, and English essay. A satisfactory laboratory record for the second and third years is required.

A brief course in surveying is taken by all students. Like mechanical drawing, this is not of the same standard as the other subjects, but on the other hand, anyone who can neither use surveying instruments nor interpret a drawing will be unduly handi-

capped at the start of his professional life. Some practical shop accomplishments are also required. They are gained in industry by many students in the summer vacations (lasting four months), after the first and second academic years. In the second summer there are, however, special advanced and supplementary courses at Cambridge. Those who do not acquire sufficient external experience are required to take courses provided in forging, machine shop work, pattern-making, and carpentry and three of these are normally required.

In addition to the lectures there are two-hour examples classes where the student attempts problems with the help of demonstrators. He can also obtain copies of the examination papers set in previous years, on which to test his knowledge for himself. His difficulties in general he takes to a supervisor whom he sees for an hour weekly. The latter, of course, would not be an authority on all the advanced subjects of part B, and many who seek distinction have further informal coaching, either privately or in small groups.

The graduate who has been through all this should have a particularly good grasp of physical principles and mathematical method, familiarity with the commoner forms of machinery and the kinds of methods used to determine their performance, the ability to carry out common drawing-board constructions as well as to interpret a blueprint, and enough acquaintance with surveying and shop practice to save him from being a mere encumbrance when he begins his practical experience.

As to the engineer as a responsible member of society, there is undoubtedly much to support the view that highly specialized technical training tends to produce types which have too little in common with other groups to make citizens capable of pulling their due weight in general affairs. It is not difficult to be a highly specialized engineer or scientist and yet remain content with spoon-feeding in matters important to society at large, but outside one's own special province. As Anatole France said, "The worst of science is—it stops you thinking." In the democratic countries we recognize that it becomes more and more important for the university to provide the inspiration to think critically and comparatively, whether the question be one of assessing the importance of a technical detail, or distinguishing between propaganda and facts.

It is a commonplace to say that the extra-curricular life of the student is just as much a part of his education as his subject work, and that the more he rubs shoulders with all manner of men, the better is he likely to understand his own situation in a complex world. While the engineering school must be relied on to introduce the student to the scientific standards of evidence and judgment, the wider associations must be relied on to form the quali-

ties of adaptation. I think we shall agree that the engineer particularly has need of both these forms of experience, for he must follow his profession with one eye to the non-technical authority, demanding compromise and tact, and another to scientific authority to which compromise is anathema.

A few words on the organization of the university as a whole will then not be out of place. Moreover it seems to me that the great differences between one variety of engineering education and another consists mainly in the great differences between one university and another. Engineering itself, of course, is essentially the same thing in both our countries. In similar courses I have myself seen no marked contrasts. Especially would I say that this is true of the better teachers. Perhaps they approach the unity of perfection! But the underlying system of the university makes all the difference to the education as a whole, to what the whole assemblage and succession of courses builds itself into.

There are 18 separate men's colleges in Cambridge, and each consists of faculty members and students in all or many subjects. Practically every student belongs to a college and has his membership of the university through it. He is in close contact with the rest of his college, at least one year being spent in college rooms. His closest official relation is to his college tutor, who does not tutor him at all in the ordinary sense, but, in the Latin of the college prospectus, stands *in loco parentis*. It is from him that the student receives his first guidance as to what to do and whom to see for advice. He sends the student to a supervisor in the appropriate subject, who sees the student for an hour weekly, and reports on him three times a year to the tutor. The latter has thus means of knowing the student personally, frequently also socially, as is true of the other senior members of the college, and of following his academic progress.

The university department generally, and the department of engineering in particular, has no supervisory or disciplinary function at all. It provides facilities, keeps a record of practical work, and conducts the examinations. It provides no special help for the backward student. Once again the onus is on the student himself. If he wishes to make up his shortcomings, he has to seek private coaching at his own cost. His tutor sees to it that he is clear as to what is expected of him.

From the student's point of view the system works very smoothly and with a minimum of visible organization. But it would be idle to deny that it is an expensive one, and this, of course, stands in the way of its wider adoption. However, a very significant number of Oxford and Cambridge students are enabled to meet the expense by various forms of scholarships and grants,

offered for competition by the state, the counties, the municipalities, and the schools, and by the colleges themselves, where they carry a valued distinction. (You will no doubt have seen the inscription "sometime scholar of such and such a college" in English text-books.) The poorest of students may therefore, if his ability is remarkable, complete his education at Oxford or Cambridge. "Working one's way through college," however, is unknown.

The general freedom of the system, which is found not so much in the curriculum as in the student's freedom to concentrate on it or otherwise, is not without its disadvantages. The opportunities are very good, but they are partly wasted, for although an undergraduate who had obviously no chance of getting a degree would not be allowed to remain in residence, there is nevertheless very little in the system to overcome mere laziness and susceptibility to distractions. The university is so secluded from the urgencies of ordinary life that it is rather easy to be idle in it. It appears to have an admirable system for the minority which welcomes all it has to offer. On the others it makes no very strenuous demands.

Your own universities clearly stand much closer to the industries for which their students are destined, and so also do the British universities other than Oxford and Cambridge. The former have, in common with your own, the division into departments of civil, mechanical, and electrical engineering. Your curricula, however, undoubtedly cover a much greater diversity of subjects, and where this occurs, the fundamental principles tend to be submerged. On the other hand there must be many who criticize the Cambridge system as academic. But is the atmosphere of practical life really conducive to grasp of principles? Is not such a grasp only to be reached after adequate private reflection? May it not be a very good thing, where conditions permit, that students, destined though they are for the most practical of the professions, should have their university years in a truly academic atmosphere?

Well, the subject is full of debatable questions, and I shall be content if I have helped to provide something of a jumping-off place for your discussion.

I have to refer to one more Cambridge matter—the influence of the schools of mathematics and physics on the engineering school. It is not without significance that in England Cambridge led the way in the establishment of engineering instruction at the university level. Much difference of opinion exists, of course, as to the proper functions of a university, and engineering as a newcomer was not received in the academic fold with open arms. Some reflection of this is to be seen in the title of the head of the

department. Although known in everyday life as the professor of engineering, his official title is Professor of Mechanism and Applied Mechanics. But the men whose early efforts set the school of engineering on its present well-defined course were of the same scientific origins as the well-known mathematical and experimental physicists of the day, although their names, with the possible exception of Sir Alfred Ewing's, would not be so familiar. They were mathematicians and physicists who, as did Kelvin and Osborne Reynolds, caught sight of the wide fields of practical application opening up for mechanics and the other subjects of classical mathematical physics. Their activities, carried on at first with a handful of students in a small annex to the physics laboratories, have evolved into a large, modern, well-equipped department, still expanding. However, in the course of this evolution the instruction in engineering has become quite independent, except that, as I have mentioned, some students spend their first year as mathematicians. It would be by no means true to describe the engineering faculty as a group of ex-mathematicians and physicists. They would prefer, I think, to be regarded as fully-fledged engineers who include some advanced mathematics and physics as part of their stock-in-trade. But as I have already remarked, the standard aimed at in applied mathematics is a high one, and there is no tendency to neglect the value of the subject both as knowledge and as an intellectual discipline for the prospective engineer.

AIMS AND METHODS OF HIGHER TECHNICAL EDUCATION IN CONTINENTAL EUROPE *

By D. P. KRYNINE

Research Associate in Soil Mechanics, School of Engineering, Yale University

This paper is based on personal experience of the speaker as student and teacher, and as observer during travels. Much information has been also found in educational literature, both European and American.

I. General Outline of Continental Systems of Higher Technical Education

Higher technical education in Europe is organized in three different ways which may be termed: (*a*) the "University system"; (*b*) the "Polytechnic system"; and (*c*) the "Monotechnic system." The University system tends to concentrate all higher studies including the technical in a university which in this case completely justifies its name since it offers to its students possibilities of a "universal" education. In the "Monotechnic" system the higher technical education is subdivided between various "schools" or "institutes" for the preparation of qualified personnel of a certain specialty (for instance, civil engineering, or mining). Such schools offer a very wide range of modern technical instruction and are not to be confused with professional schools training more specialized engineers who are deprived however of a wide scientific outlook. Finally, aggregations of several monotechnical schools form higher schools of the "polytechnic" type termed "Technische Hochschulen" in German, which term is usually translated into English as "Technical University." A European "Technical University" corresponds more or less to an independent and enlarged "School of Engineering" of an American university.

At this stage of the exposition it should be mentioned that although in this country the university system prevails, there are here excellent specimens of schools of both polytechnic and monotechnic type. The respective examples are the Massachusetts Institute of Technology and the Stevens Institute of Technology, the latter giving mechanical engineering instruction only.

* Paper read at meeting of New England Section, S. P. E. E., Burlington, Vt., Oct. 10, 1936.

II. Systems of Higher Technical Education as Applied in Different Countries

(*a*) *France.*—The so-called "great schools" (Grandes Ecoles) form the nucleus of French technical education. Most of them are monotechnic; thus the School of Bridges and Roads prepares civil engineers; and two Schools of Mines—mining and metallurgical engineers, and also railroad specialists. To this number of monotechnic schools belong also the School of Naval Engineering (Ecole du Genie Maritime), the Superior School of Electricity, and the new Superior School of Aeronautics. On the other side the "Central School of Arts and Manufactures" is a polytechnic school preparing mechanical; structural; mining and metallurgical; and chemical engineers. But the polytechnic character of this school is far from being identical to German polytechnic schools as discussed hereafter, since the theoretical teaching is common for all specialties and the difference consists in exercises and practical training only. It may be said so far as institutions of higher learning are concerned, that there are no "polytechnic schools" of the German type in France, although some schools of a somewhat lower scientific level (for instance "Ecole des travaux publics" in Paris) approach the German type closer.

The "University system," which is practically the only one in use in England, found some reflection in France. Approximately, up to 1890 the French education slogan was: "pure science to universities; its application to special schools." But since then a number of universities, principally in the provinces have opened their doors to technical sciences (mostly electrical and chemical engineering). Technical education has been organized within the Universities Scientific Schools (Faculte des Sciences) under the form of special "institutes." The latter are either of higher scientific value and without any hesitation may be called institutions of higher learning; or, as in most cases, they have a purely professional character. For instance, Grenoble University possesses a higher electrotechnical school with a special section for engineers already graduated by other institutions of higher learning; and at the same time has a professional electrotechnical school.

(*b*) *Germany and Other Countries Adopting the Polytechnic System.*—The prevailing school type in Germany is the "polytechnic" school (Technische Hochschule). There are ten of these schools in that country; and a couple of the "monotechnic type" (for instance Mining Academy, Freiberg i/S). Countries which have adopted the German polytechnic type are Switzerland, Holland, Austria, Hungary, Czechoslovakia, Poland, and others. The principal Italian schools are also of the polytechnic type. Departments or "faculties" of a polytechnic school generally are: civil

engineering and architecture, mechanical, electrotechnical, chemical, mining and metallurgical engineering, sometimes aeronautics, shipbuilding, agriculture, mathematics, and physics for teachers. The Engineering School of Turin (Italy) has a graduate school of artillery and ballistics.

(*c*) *Russia.*—The first Russian technical schools were founded about one hundred and twenty-five years ago under the influence of the French "great schools" and before the war had a five-year curriculum which corresponds approximately to two years of the French "Ecole Polytechnique" plus three years of a "great school." Some modern Russian schools were of "polytechnic" type and had a four-year curriculum. After the revolution there was a marked tendency to subdivide the existing schools or "institutes" into smaller "monotechnic" schools specialized along different branches of industry and technique.

III. Admission of Students: Their Age

It is more difficult to gain admission to a French "great school" than to any other European institution of higher learning. As an example, let us follow the career of a French boy eighteen years old who is about to be graduated from a high school (lycee) with the degree of "bachelor" and who wishes to become an engineer of roads and bridges (Ponts et Chaussees). To enter the corresponding great school he has to pass a competitive examination ("concours"); and to become a government engineer, he has to pass first through "Ecole Polytechnique"; so he starts to train himself in mathematics, descriptive geometry, physics, etc., in the same high school or some other high school under supervision of special teachers. This preparation may last two, but as a rule, three years. A candidate cannot be admitted to a "great school" before twenty.

The entrance examination to the Ecole Polytechnique consists of two parts: (*a*) a written and graphic test in different towns of France; (*b*) a definite, chiefly oral, examination in Paris for those who passed examination "*a*." The theoretical grounding in higher mathematics and science required is approximately that of a junior in an American engineering college. The "Ecole Polytechnique" has nothing in common with schools of the German polytechnic type, but the name; this is a military school with a two-year curriculum based principally on mathematics, mechanics, history, literature, social sciences, military science and exercises; very little technical instruction is given. Whether a candidate is able to enter a "great school" he desires, depends on his ranking. The number of vacancies in a great school is very limited, and a graduating class in "Ecole Polytechnique" numbers about two hundred and

twenty-five students. Thus instead of entering the school he desires, the candidate whom we follow in this paper, may simply become an artillery or army engineering officer, since the "polytechnicians" of lower ranking go to the army or to industry in some way. If the candidate is successful, he may be admitted to the second year of the great school and after two years of study, at the age of about twenty-five, he becomes an engineer. Instead of trying to enter the "Ecole Polytechnique" the candidate in question could also undergo competitive examinations for admission to the first year of the "great school"; but he would be in a less privileged position than a polytechnician.

The French universities and all continental schools of the "polytechnic" type, such as German and others require only graduation from a secondary (high) school. It is to be noted that German secondary schools give more training to their graduates than the American high schools, particularly in mathematics. The duration of the studies in a "polytechnic" school is generally four and one-half years, including the period of final examination; and five years in some Italian schools. Thus a candidate may become an engineer earlier than in France, say at the age of twenty-three or so years.

The old Russian technical schools admitted students on competitive examination in elementary mathematics; physics; and composition. A successful candidate graduated in the spring in a "gymnasium" or "real school" entered the high technical school the fall of the same year, after a few months of summer mathematical work. Many failed, however, and were obliged to lose a year or choose another career. The average graduation age was about twenty-four, but in many cases higher.

Thus French institutions of higher technical learning require longer preparation than in other countries; hence the graduation age is higher. This state of things aroused alarm in France; books were written on the subject, and technical societies dedicated entire meetings to the discussions of the problem. Owing to a certain conservatism and the wonderful "esprit de corps" of the polytechnicians who defend the system, very little was done in this province.

The events which took place in Europe after the World War brought with them certain limitations in admission due to political reasons, as in Russia and Germany. Besides these purely political reasons, the Reich government generally decided to decrease the number of students in the institutions of higher learning. It appears from the "Year Book of Education for 1936" published in England (p. 137) that a German Dr. Wohlfahrt assisted by the Rockefeller, Carnegie, and later by the Abraham Lincoln Founda-

tions, elaborated a system of written examinations which consists in a multiplicity of questions on common life and the elements of general science. In grading answers, not only the right answer, but principally the method of approach to the solution is evaluated. Only representatives of each secondary school are tested; and each school obtains a "quota" according to the grade of its representative. The selection of the scholars themselves within this quota is purely a matter for the school. The best answers came from the children of clergymen (average grade 84) followed by those of the university teachers (average grade 70).

IV. Methods of Teaching

(*a*) *France.*—Years of mathematical preparation make the French student very mathematically minded and rather one sided since often he underestimates everything which is not mathematics. At the same time such a rigorous training has certain advantages since it tends to form an intellectually homogeneous student body, fully disciplined in work habits and able to follow a mathematical lecture with great facility. Since the teaching staff has passed sometimes through the same routine, there is a mutual understanding between the professor and the student, which makes the lecture system completely acceptable; and this system is the only one used in French "great schools." It is to be noted that besides the oral lectures, most professors have their courses published either in printed or lithographed form which greatly helps the students. As the academic year progresses, there are permanent examinations, at least in the principal subjects, which change from one week to another to form a cycle. Exercises and "projects," or designs of structures and parts of machines, and laboratory work, occupy a time practically the same or somewhat more than the oral teaching "ex cathedra." These exercises are mostly individual or confined to a group of students and are made under supervision of instructors who, of course, may be consulted, but asking questions of a professor during a lecture is not customary. As an example, a three-year schedule of the School of Mines is given:

Lectures	1096 hours	or	45%
Graphs and projects	586 "	"	
Laboratory	488 "	"	55%
Different studies	283 "	"	
	2453 "	"	100%

In the summer (July 1–October 15) the students of "great schools" are sent to practical work according to their specialties (construction jobs, factories, mines, etc.).

The number of students in French schools is very steady, since owing to the careful selection of students and strict discipline in the school, students do not fail, and as a rule, the number of graduates is the same as that of the newly admitted. The statistical data for the academic year 1934–1935 are (numbers in brackets are estimated):

Roads and Bridges	113
Mines (120) + 137	257
Electricity	180
Aeronautics	220
Genie Maritime	40
Ecole Centrale	750
Universities	(1200)
	2760

The number of graduates every year should be estimated somewhat under one thousand men.

(*b*) *Germany.*—While the French discipline is very severe and all students of a class follow exactly the same routine, German "polytechnic" schools are more elastic, but at the same time more specialized. The student is free to work out his own program and schedule and follow it; but he must undergo two thorough examinations during the course of his studies; a preliminary, at the end of his second year of studies, and a final examination. An example of a schedule recommended by the Berlin Technical University in 1934–1935 is:

MECHANICAL ENGINEERING, 1ST YEAR

	1st term		2d term	
	Lectures (hours)	Exercises (hours)	Lectures (hours)	Exercises (hours)
Higher Mathematics	4	2	3	2
Descriptive Geometry	2	2	–	–
Physics	4	–	2	4
Chemistry	1½	–	1½	–
Mechanics	4	2	4	2
Introduction to Practical Mechanics	2	6	2	4
Mechanical Technology	1	–	1	1
Metallography	–	1	–	1
Electrotechnics	–	–	2	–
Economics	2	–	2	–
	20½	13	17½	14
	33½		31½	

Lectures "ex cathedra" prevail in Germany; but, as a rule, they are more illustrated by the use of models and are closer to practical life than in France. Special "institutes" (chemistry; mechanics; electricity, etc.) are at the disposal of the corresponding professor to illustrate the teaching. "Exercises" follow lectures; these are examples; problems; or discussions under the close supervision of the professor's assistants. Finally "projects" which can be carried out under different professors, resemble French ones and represent a detailed solution of a technical problem.

As soon as a student has completed a course and the necessary exercises, this fact is recorded by the professor or his assistants in the student's recording book; and an analogous record is kept in the professor's files. Projects and exercises also carry signatures of instructors. The scope of the examinations to be passed is the following (Civil Engineering):

First Examination:

(*a*) Evidence of work done.
(*b*) Written tests and tests in the drawing room (mathematics. mechanics, construction).
(*c*) Oral examination in basic engineering subjects (mathematics, descriptive geometry, mechanics, physics and chemistry, geology, surveying, constructions, general knowledge of machines, economics).

Final Examination:

(*a*) Evidence of the work done.
(*b*) Diploma "project" (six weeks).
(*c*) Three six-hour tests in the drawing room.
(*d*) Oral examinations in different engineering subjects.

The number of students in German institutions of higher technical education is subject to fluctuations. Statistical data concerning the total number of students in ten principal German schools for the period 1926–1935 show a rise from 1926 to 1931, so that the years 1930 and 1931 were those of maximum "prosperity," so far as the number of students is concerned. A sharp decline started in 1931 and apparently has lasted till now, since the trend of registration curves in 1935 shows no recovery. The number of students which was 25,915 in 1931 fell to 12,732 in 1935, a decrease of about fifty per cent in four years. Under normal conditions the number of students was about 22,000; so that at the present time German "polytechnic" schools work at half capacity.

The distribution of students among different specialties in 1934–1935 was:

Civil Engineering	26.3%
Mechanical Engineering	28.3%
Electrical Engineering	22.1%
Chemistry	12.1%
Mining and Metallurgy	7.7%
Shipbuilding, Aeronautics	3.5%

This proportion is misleading, however, since the number of students in different departments was falling unevenly. For instance, the ratio of the number of mechanical engineering students to that of civil was 3 : 1 in 1931 and 1 : 1 in 1935. The number of students in civil engineering practically did not drop; and apparently this fact can be explained by a certain need of engineers for great public works which have been under construction in Germany. The general decrease of the number of the students during the period 1931–1935 can probably be traced to the influence of the economic factors such as the world depression.

The number in the graduating classes is about fifteen per cent of the total so that the "graduation ratio" is 0.15. Multiplying the graduation ratio by the normal duration of studies (4½ years), the "successful students' ratio" should be obtained. The value of this ratio equals 0.67 or about two thirds; and this means that one third of the students in German technical schools are not able to follow the normal course. It is interesting to compare this fact with the stability of the number of French students.

(*c*) *Russia.*—A system similar to that of the French "great schools" was used in Russia prior to 1905. There was the lecture system and the students of the two lower classes had weekly examinations or "repetitions." The third and the fourth-year students had examinations at the end of the year only, during a period of 1½–2 months. In most high technical schools there was also a fifth year dedicated exclusively to "projects." Two summers had to be spent on the job; in a factory; or on a locomotive. Between 1905 and 1917 there was a system approaching the German; the students studied according to their own schedules. The results were not favorable since the duration of the studies increased to 6, 7, and more years. The students spent more time in study than necessary, and the examiners became more rigid than before. There was an experimental period after the revolution. The lecture system was abolished, but re-established after innumerable trials-and-errors. At the present time there are lectures given by the professor who tries to discuss principles only. Classes are numerous, and students are divided into groups (15–30 men), one of the groups is headed by the professor himself and others by instructors. Each lecture is followed by "exercises," each group working in a separate room. The "exercises" resemble to a cer-

tain extent the American class-room system. There are additional explanations of the lecture; solving problems and discussing examples; offering and answering questions, etc. Results of these exercises are discussed by the professor and his assistants in special conferences. Graphical and laboratory exercises in the programs are abundant, but on many occasions the necessary equipment is lacking. Schools are in close contact with industrial and constructing concerns.

V. Research and Post Graduate Work

There is no such subdivision of students into "undergraduates" and "graduates" as in this country. All students are of the same category and upon graduation receive an engineering diploma. If an engineer wishes to obtain a doctor's degree ("Dr. Ing." in Germany and some other countries) he has to submit to the school a piece of independent research, to undergo a strong examination in some subjects connected with his chosen specialty and defend his dissertation. The number of "Dr. Ing." in Germany is very large; perhaps seventy-five per cent of the teaching staff in the high technical schools possess a doctor's degree. In France the doctor's degree for engineers was introduced about 1923, and strangely enough, this degree is given not by the technical schools, but by the universities. The number of doctors—engineers in France is insignificant. In Russia this degree was introduced before the war, but abolished by the revolution.

"Projects" carried out by European students require an intensive search in libraries; getting information at the factories; and other work which may tend to the rational solution of a given, often complicated technical problem. But this is not "research" in the full sense of this word. Exceptions are perhaps diploma-works of chemical or metallurgical students who have to solve a laboratory problem.

Research is reserved to engineers already graduated by the school. In France these are assistants to a professor, helping him in his laboratory; or some "volunteers" from outside who have obtained permission to use the school's equipment, and in the case of the "University system," regular workers of a given "University" research institute. The German polytechnic schools all possess excellent research installations and a regular staff of research workers, and do outstanding work for industry. The interest with which the German institutions of higher learning follow the progress of technical science, may be illustrated by the example of the soil mechanics laboratory at the Freiberg Mining Academy which, besides excellent equipment, possesses a staff of two

research assistants; one physicist, one helper, one master mechanic, four apprentices, total nine men, without taking into account the practicing engineers who come to work periodically in the laboratory. Soil mechanics is a new science and has not been introduced as yet into the curricula of most American institutions.

The post-revolutionary research work in Russia has been described very many times in the literature, and speaking impartially, it is of a high grade. But the research institutes are, as a rule, separated from the schools. However, professors, instructors, and often students take active part in the life of the research institutes as additional workers.

VI. Teaching Personnel

As a rule, a continental professor is a mature specialist and teaches one subject only. In general professors are up-to-date on the practical side of the branch they teach; and many of them are connected with industry as consulting engineers or designers. Many professors hold government offices, for instance in the French great schools where professors often act also as high officers of some technical administration.

Since European technical schools are located in great centers, there is a fine opportunity to have lecturers from actual practice. The number of men on the teaching staff and the subdivisions of subjects in some German schools is astonishing. For instance, the Berlin-Polytechnic School has seventy-nine men in the division ("Faculty") of civil engineering which is also in charge of Architecture. The department of mechanical engineering in a smaller school of the free city of Danzig has a staff of twenty-four. Full professors, however, are not very numerous.

The political events in Germany, Russia, and Italy have changed very much the conditions of appointment of professors. The speaker is well acquainted with the Russian method of appointing professors which was as follows: When there was a vacancy, a notice was published in special journals and sometimes in the newspapers. Any person graduated from an institution of higher learning could apply; and a special commission within the school, considered the scientific works of each candidate and his general characteristics. Then a secret ballot was cast on all the candidates, first by the members of the division interested in the election and afterwards by all full professors of the school. The elected candidate was confirmed in his office by the Government. In Minister of Education three names, from which the Minister made his choice.

VII. Aims of the Higher Technical Education in Continental Europe

Practically all the institutions of higher technical learning in Continental Europe belong to the Government. Hence it is obvious that in the first place a school has to conform to the requirements of the Government. As a rule, the so-called "democratic" governments exert only a general guidance of the school, giving it what is called "autonomy." Otherwise, the school becomes a part of the administrative machine and is entrained into politics. Furthermore, the activities of a school depend on the reactions of society as a whole and of industry. Thus the final system of a school is a resultant of these three influences. The physical and economical environment of a given country are, of course, of great importance. Without entering into details and drawing conclusions from the facts observed, the aims of the higher technical education in different countries may be formulated as follows:

(*a*) *France.*—The aim of the "great schools" is to create an "elite" capable to direct the national technique. This aim is supported by a certain part of the French public; but does not satisfy industry. Under the influence of the latter, "Ecole Centrale" was established, followed by Universities' technical institutes.

(*b*) The aim of the *German* system is to create an army of well trained engineers capable of developing national resources through highly graded techniques. There is no competition before entering a German school; but there is a strong competition in actual life. The new regime introduced some modifications into the German system, namely: (1) limitation in number of students; (2) physical education; (3) participation in politics by faculty and students.

(*c*) The aim of the *Russian* system is to develop as many engineers as possible in order to "industrialize" the country and to strengthen the existing regime.

It is a sad thing to state that all European countries consider the engineer as a mighty war weapon and prepare him, openly or in a disguised form, for the aims of war.

VIII. European Views on Higher Technical Education in America

The general features of the American system of higher technical education are well known in Europe although the literature

on the subject is not abundant. It is quite logical that in the first place the attention of an observer should be attracted by these features which seem to be undesirable in the "home system." Such is the case in France where there is a certain opposition party requiring that students be graduated at a lower age; that their mathematical training be more reasonable, etc. In this connection the following points are considered desirable: (*a*) the low age of American graduates (estimated at 21); (*b*) not exaggerated courses in mathematics; (*c*) the abundance of laboratories and workshops. French observers believe that the American engineer is being formed not in a college, but on the job during the first two years of his practical work.

Germans apparently consider their own technical schools higher in all respects than the American. The rector of the Karlsruhe technical school, Dr. Probst, said in 1927 that although there are highly developed institutions of advanced technical learning in America, some others graduate students who are not more capable to do independent work of high grade than German graduates of middle technical schools. Dr. Probst attributed this circumstance to the absolute lack of research work in the corresponding American institutions which circumstance, in his opinion, makes the teaching "lifeless" ("leblos").

To conclude, allow me to give you a few of my personal impressions. I think that the American student body is very eager to learn and is more mechanically minded than its European counterpart, which facilitates the teaching. A certain lack of mathematical knowledge may easily be corrected by introducing special courses in mathematics in the junior year as is already done in some electrical departments. I think, however, that in this country mathematics is not enough used in teaching technical subjects and that there is a gap to be filled between mathematics and engineering. Furthermore, I believe that most of the enginering teachers should do research in some way. In doing so, they not only contribute to the general advancement of science which is one of the major tasks of every institution of higher learning but also benefit themselves. This is because research for an intellectual mind is the same as physical training or athletics for the body. A teacher who at the same time is a research worker generally is able to keep his mind elastic, alert, and up-to-date up to an advanced age; and in personal touch with the student, he communicates to him a part of his inquiring attitude and of his capacity to adequate generalizations from facts observed, so necessary for a successful engineer.

CONCERNING THE IMPORTANCE OF TEACHING SCHOOL *

By HARDY CROSS

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Some years ago a man asked me, "What are you—a research man?" I replied, "No, I'm a plain school teacher." He at once turned to give his attention to men doing more important work.

The title of his talk was chosen with some care to suggest that the point of view here presented is old fashioned. I am speaking of school teaching (o.s.), not of "educational activities" (n.s.). A friend distinguished as an educator divides teachers into two groups, those who are attending to their jobs and those who are busy fixing the world. I am now speaking of the first group.

Everyone honors the school teacher with mental reservations—many reservations. "Those who can, do; those who can't, teach." I believe someone has added, that often if they cannot do either, they can at least administer teaching. It is to most of us a matter of common observation that many men in practice feel quite sure that they could teach very much better than do we; obviously, to them, it is a matter of knowing the facts to be taught and not at all of learning the art of teaching.

I wish I could paint like Rafael. A novice asked Rafael with what he mixed his paints. The master replied, "With brains." Teaching is an art—one of the finest of all the arts. A dean is said to have told his faculty, "I assume you are good teachers; your rating with me depends on your publications." I like the frankness of that! But everyone who daubs a canvas is not a Rafael.

Teaching is an art. It is not a science. One of the most intellectually disintegrating influences of to-day is the idea that all human activities can be mastered by the methods of the physical sciences. As an art, teaching is necessarily individual; it must adapt itself both to him that gives and to him that takes as well as to the subject taught. We can teach by lecture or by discussion. Almost certainly the most valuable course that I ever took as an undergraduate did not contain a single assigned problem; but some teachers use numerous assigned problems with success.

* Address before the Illinois-Indiana Section, S. P. E. E., Chicago, April 18, 1936.

I have heard that teaching is just a job, like any other job. In a sense that is true and it needs emphasis. A teacher's first job is to teach, not to write or to do conventional research or to make speeches or to run errands on academic or technical committees, but to teach. Do not misunderstand me; for a teacher to keep his feet on the ground, to keep in touch with the spirit of actual work as distinguished from the hot house atmosphere of a school he must serve on technical committees and attend conventions. It is there that he is told bluntly that he does not know what he is talking about; and most of us need that badly, for the intellectual mortality among teachers is deplorably high.

Scholarship? Of course. How can the blind lead the blind? The great teacher must know his field, must know it in a peculiarly clear vivid way. He will not only be a thinker but an original thinker in his field.

Productivity. A teacher constantly trying to master his field, almost inevitably produces—research, books, articles, addresses. The by-product should be valuable, though much of it is not because so few academicians know when to use waste baskets.* The output will have value, if any, because of its quality not because of its quantity. But all this does not affect the fundamental truth; the teacher's job is to teach.

Research. Oh, yes, that goes with scholarship. Hard and intelligent study of any field of knowledge inevitably leads to research, if by research we mean systematic investigation; in fact the distinction between the two is not clear. If the hard work is guided by the intellectual equivalent of fasting and prayer—really wanting to know, really caring enough about knowing to think hard—it will often be valuable research. But this is an incident to the teacher's work. He wants to know not in order to be a "research man" but in order that he may teach well. That's his main work.

Teaching is an art. The teacher's job is to teach. What shall he teach? The amount taught is certainly not very important. Any one of us can take one or two books in almost any field and get from them over the week-end more information than an undergraduate would acquire in a semester's course, and vastly more than he will remember. Notice that I said more information, not more understanding. If that undergraduate has been well taught he will know what part of this information is fundamental and what part ephemeral, what part is important and what part is in-

* I once said that I wanted to write a monograph on the construction and use of waste baskets. A scholarly colleague in another field commented: "The design of waste baskets is an engineering matter; their use is a moral issue and so out of your field of study."

cidental. Under a great master he will have formed some basis for critical judgment in the field.

What shall he teach? That is one of his great responsibilities. Doctors take the oath of Hippocrates. We, too, assume when we teach, a responsibility to determine what shall be taught, what to leave out, what to emphasize—especially what to leave out. That responsibility does not rest with the dean, certainly it does not rest with the student. It is so easy to give the student what he likes, to give a popular course. But there is no escape; the responsibility is mine to decide what to emphasize, what to omit. I may add here that it is my job to teach, and the student's job to learn. He is there, please, to study how to do research; it is pretty bad to tell him he is already a research man.

The curriculum. I confess that I care little about it so far as teaching goes. It is usually revised every few years and the revision is often hailed as the beginning of a new era in education. But I think all the new developments could fit quite as well into the curricula of thirty years ago as they do into the more modern ones. That revision of curricula for administrative purposes or for advertising purposes is often desirable is another matter.

How shall the teacher teach? By winning the affection of these trusting souls that they may gladly follow where he leads and that their minds may flower to perfection in the glad sunlight of love and sympathy. Now that is fine, but as the mathematicians say, it is neither necessary nor sufficient. I am talking of teaching, not of running an intellectual nursery. Some of the most popular teachers that I have known were, I am convinced, mighty poor teachers. Some of the greatest teachers I have known have not been loved. Students, I find, are generally fair and about as much in earnest as their teachers. They will follow the lead of the teacher who has mastered his subject and his art. They may not love him, nor need they do so. A good many so-called popular teachers achieve popularity by prostitution of their art—and students know it. But it is an easy way out.

Again, how shall he teach? I am very suspicious of any specific answer to that question. And I am very, very sure that uniformity of method is the last thing we want. It is not necessary that all pictures of girls be Gibson girls; we can do with a few pictures such as Rembrandt's mother. There are many kinds of teachers, many fields of thought. Even in the same field of thought different men approach their subject by different paths. There are several approaches to even the most specialized subjects. If they can be presented without too much confusion—and I am emphatic in adding that often they cannot be—all of these points of view are profitable.

And how shall we identify this great teacher? Well, we often do. Often we do not. Rafael was a great painter, but I never heard that it was because his dried paint had a high Brinnell number. But it is inevitable that this art, like other arts, must often be its own reward. I suspect also that it is inevitable that the administrative type of mind is usually quite different from the teaching type, that many excellent administrators have trouble in recognizing a great teacher when they see him. It is also true that most of us are somewhat like the asylum inmate who said "That fellow over there thinks he's Napoleon; he's crazy, I'm Napoleon." But sometimes we all agree on the greatness of some inspired teacher.

Teaching facilities—lantern slides, fine desks, handsome buildings. They are all right, but I have observed that the really great teacher will, to use a homely phrase, teach in spite of "hell and high water." Great buildings and expensive laboratories can never make a great university; great teachers do.

I doubt if I have ever become a good teacher, but I have known many very good teachers. I think I have known several really great teachers, though they are scarcer than gold dollars. They have been of different types; some have been great graduate teachers, some gifted in the undergraduate field. I have recognized them by the vision, the inspiration, they gave to the men they trained.

There are many who think as I do that these rare great teachers are the most important men in the educational world.

THE COMPREHENSIVE EXAMINATION; DOES IT APPLY TO THE ENGINEERING CURRICULUM? *

By L. M. K. BOELTER

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The subject of examinations deserves careful analysis from the point of view of the student as well as that of the faculty. Let us first turn to Leacock's pasquinade, "The Apology of the Professor." The following quotation will suffice to introduce the topic of this paper, the comprehensive examination. "The supreme import of the professor to the students now lies in the fact that he controls the examinations. He holds the golden key which will unlock the door of the temple of learning,—unlock it, that is, not to let the student in, but to let him get out,—into something decent. This fact gives to the professor a fictitious importance, easily confounded with his personality, similar to that of the gate keeper at a dog show, or the ticket wicket man at a hockey match."

Before proceeding with the discussion of the comprehensive examination a few general remarks with respect to examinations would seem to be in order. According to Ruch † the present purposes of an examination may be grouped as:

1. Motivation of the student for learning.
2. Maintenance of standards of accomplishment by the instructor.
3. Training in the use of the language (English).
4. Measurement of the accomplishment of the student.

The effectiveness of an examination as training in English cannot be defended because the conditions of an examination period are not favorable to proper expression. The traditional essay (*i.e.* discussion type) examination will not bear severe scrutiny as a criterion of student accomplishment. This type of examination often reflects the knowledge, attitude, and prejudices of the reader.‡ The greater the number of criteria which are applied by the reader to determine the correctness of the solution the lower will be the grade and the narrower the band of spread of grades. In engineering pedagogy the discussion question is often alternated with substitution exercises. After the student has successfully inter-

* Presented at the Fourth Annual Meeting of the Pacific Southwest Section, S. P. E. E., Stanford University, December 1935.

† "The Objective or New-Type Examination," p. 10.

‡ Ruch, *ibid.*, p. 20.

preted the latter type, the solution resolves itself into a substitution of numbers into previously memorized expressions, or into an expression found in the book in the case of an open book examination. Sufficient time is not allowed the student for the derivation of the expression in case he does not remember it. He should be given credit for the correct interpretation of the question but the judgment cannot always be equitably rendered by the examiner. The answers to discussion and substitution type of questions may be criteria of memory (over-learned facts), mental agility, and the student's adaptability to the environment consisting of the classroom, instructor, and textbook. The results, in the case of the average student, will be indicative of his ability to react to unusual mental situations during a period of abnormal mental stress. That this type of experience is good training has been accepted.* The results will not necessarily yield a measure of the power of the student to analyze or synthesize a problem.

The analytical question requires that the student separate an actual system into component ideal systems (or system).† An ideal system is defined as an assemblage of objects united by regular interaction in which but one energy field exists. The energy field obeys idealized initial and boundary conditions of the actual system. The idealization of an actual system is usually called "making assumptions." In the substitution type of problem, the idealization process has been performed by the examiner. The process of analysis demands the exercise of judgment. The analytical question offers the opportunity of measurement of the extent of the exercise of judgment under abnormal mental stress. In addition, problems involving synthesis, that is, the application of the basic laws (which describe the behavior of ideal systems) to actual systems should be included in an examination.

Some objections to analytical questions are:

(*a*) The length of time required for the solution of this type of question.

(*b*) The student may reach an impasse due to lack of factual ‡ knowledge and thus not be able to demonstrate analytical power.

(*c*) Evaluation of the student's judgment by the reader is a difficult process.

* W. A. Hillebrand, "The Function of Examinations in the Engineering Curriculum." December 1935 Meeting Pacific Southwest Section, S. P. E. E., Stanford University.

† L. M. K. Boelter, "Mechanical Engineering Laboratory Practise." JOURNAL OF ENGINEERING EDUCATION, May 1936, p. 747.

‡ Factual knowledge is assumed to consist of the description, assumptions, definitions, nomenclature and symbolism necessary to define an ideal system as well as the basic laws which describe its behavior.

The algebraic symbolism used in engineering instruction increases the difficulty of evaluation because the student has not really mastered this art of expression (indeed, may we assume he has mastered the art of English expression?). In any type of examination adequate sampling of the student's educational experiences must be accomplished. It must be remembered that the reaction of a student is based entirely on previous educational stimuli and his native intelligence, that is, his answers represent a recombination of earlier experiences.

The objective examination * has been offered as an additional type, classifications of which are: (*a*) True-False; (*b*) Multiple Choice; (*c*) Completion; (*d*) Matching. The chief advantages of this type of examination are:

(*a*) The wider scope of subject material contained within the examination.
(*b*) Less mechanical effort required of the student.
(*c*) The validity of the examination is higher, that is, it more truly measures what an examination is intended to measure and is less influenced by the idiosyncrasies of the examiner.

It would seem that the modern examination in engineering should contain the elements of discussion, substitution, analysis and synthesis, and objectivity. It should reveal the power of the student rather than those tasks which he cannot perform. The writer believes that this can, in general, best be accomplished by a limited form of open book examination.

The administration of the comprehensive examination for the M.S. degree for those students majoring in mechanical engineering at the University of California will be described briefly. The policies were formulated by the Committee on Graduate Study and Research under the Chairmanship of Professor J. E. Younger. After a semester of graduate work (or at a later time) the student is scheduled to take the first portion of the comprehensive examination (three hours, written) which deals with a review of undergraduate work. It consists of those portions of chemistry, physics, and mathematics which are particularly applicable and were used in courses in electricity and magnetism, mechanics, hydraulics, and heat power engineering with applications from the latter group of courses.

Mechanical engineering was arbitrarily divided into the followlowing fields of study by the Committee: Heat, applied mechanics, economics of engineering, fabrication of materials, and fluid motion. The student is allowed to choose two fields in which he must demonstrate, in two three-hour written examinations, his ability in the

* Ruch, *ibid.*, and Ruch and Rice, "Specimen Objective Examinations."

second portion of the comprehensive which is scheduled at a time just before the student expects to receive the degree. I consider the element of choice to be very important. The student bases his choice upon his training in course and in research. The examinations are administered by various faculty committees. Experience has shown that a specific reference (or references) should be posted for each field and that the student should be held responsible only for such methods as may be based upon the subject material contained therein. It is the opinion of the writer that the questions in the two fields should be closely articulated but this procedure is not possible at the present time because it would require too many examinations. The reasons for this view will appear later.

Oral examinations have not been used because (*a*) the time required is fairly great, (*b*) the examiner is inclined to answer the questions for the student, (*c*) experimental study of the effectiveness of the type of examination is lacking, (*d*) its chief value seems to lie in stimulation toward remedial study.*

A properly conceived comprehensive examination should measure the ability of the student to articulate and integrate his educational experiences. These stimuli have been received under various conditions. In the school system knowledge is arbitrarily divided into courses and fields of study. The student is subjected to courses given by experts in that field. An expert, by nature, can be of little aid to the student in the matter of correlation of subject material between different fields.†

It may then be argued that a comprehensive will serve as a goal toward which a student may focus his efforts. Courses will not be considered as separate entities but as preparation toward an end, thus stimulating integration. In reply to this point of view I wish to state that the burden of integration is *too great* for the engineering student. He does not possess a well defined concept of the scope of engineering upon entering college. He does not view it from its fundamental aspect, *i.e.* the utilization of the forces of nature for the benefit of mankind. For the purpose of the ensuing discussion this statement will be briefly analyzed. The laws of nature fall into four groups:

(*a*) Properties of Substances (Chemistry and Physics).
(*b*) Mechanics (Fluids, Solids, Sound), Elasticity.
(*c*) Heat (Light), Thermodynamics.
(*d*) Electricity (Magnetism).

At bottom two principles are the most important: the conservation

* Ruch, *ibid.*, p. 18–19.

† H. J. Laski, "Limitations of the Expert." *Harper's Magazine*, December 1930.

of matter and the conservation of energy, and further, these two laws are identical in relativity theory. By concentrating upon energy transport and transformations the similarity of behavior of the various systems under the action of different energy fields becomes apparent and the powerful tool "reasoning by analogy" is developed.

The engineering student does not view mathematics as a mode of expression of physical processes but rather as a separate entity. The gap between training in mathematics and its utilization in engineering courses is great.* Professor Kucharski at the Technische Hochschule of Charlottenburg presents elementary experimental evidence in kinematics and mechanics and then immediately introduces mathematical differentiation and integration. It may be suggested that elementary college mathematics and physics and parts of chemistry be presented in engineering subjects and not as separate courses. In reply my critics will state that the point of view expressed by mathematicians, physicists and chemists in the courses of instruction are absolutely essential to the engineer. This view is correct. However, it may be maintained that often elementary instruction in college mathematics, physics and chemistry does not satisfactorily reflect the modern point of view in these fields and further that the modern point of view can best be presented in courses in the basic sciences scheduled late in the curriculum. Physics 107 prescribed for electrical engineering students in the communications option at the University of California may be cited as an attempt to present a view of modern physics to seniors.

The second part of the definition of engineering demands "utilization . . . for the benefit of mankind." This phrase introduces such phases as design, manufacture, construction, sales, and operation. Cost enters engineering problems as a new variable. The fields of economics, psychology, history, and social science become integral parts of engineering. The student *cannot* be expected to entirely fill this gap in his educational experiences of his own volition or by prescription of courses in these fields. The modern engineering course must include these variables (it does so to a surprising degree but not always in a manner recognizable by the student). Courses M.E. 113 and E.E. 113, offered to seniors in the mechanical and electrical curricula at the University of California, Berkeley, partially satisfy the demand for the articulation of the humanities and engineering.† An important aim in this

* R. G. Minarik, "Are We Teaching Engineering Mathematics?" JOURNAL OF ENGINEERING EDUCATION, March 1935, p. 499.

† B. M. Woods, "Public Speaking and the Pursuit of Culture," JOURNAL OF ENGINEERING EDUCATION, April 1934, p. 562.

course is to orient the student with respect to experiences of his everyday life as well as in the engineering profession.

Industry requires men who are capable of integrating their engineering experiences. The point will be illustrated by several examples:

(*a*) Was the appearance of the ball bearing electrical motor retarded by the fact that the motor was thought of primarily as an electrical and magnetic circuit and empirical rules were used to design the bearings? The bearing represents a problem in fluid mechanics.

(*b*) Does the engine designer consult a reference on electrical filters for aid in the solution of a vibration problem?

(*c*) Does the designer of a transmission line consult references in aerodynamics and mechanics for detailed information regarding the vibration of a line? It is my experience that he does not but instead consults books on the general subject of electrical engineering.

The conclusion which may be drawn is that the comprehensive examination may serve as an incentive to the student to integrate his educational experiences (not necessarily his technical experiences only) but that the task which lies before him exceeds his capacity. The examination will become effective in this connection only after some change in our educational procedure. The present state of knowledge with respect to examinations (both written and oral) precludes obtaining data, by means of a comprehensive examination, with respect to the student's ability over and above that known from other sources, such as course grades and performance on research. The examinations are more than likely to be measures of "Overlearning"* or of knowledge of subject material reviewed just before the examination.†

One result of the experience of the mechanical engineering staff with comprehensive examinations for the degree, Master of Science, has been the introduction of course M. E. 124ab as an elective. The description of the course is as follows: "Basic physical concepts and their application to the fields of mechanics of machinery, elasticity, thermodynamics, heat transfer, and fluid mechanics, with special emphasis upon the method of attack employed in the solution of engineering problems. Modern contributions from the current literature. Theoretical analysis will supplement the experimental work of course 131A–131B (mechanical engineering laboratories)." It may be observed that one object of the course is to aid the student in the integration process. The comprehen-

* Peter Sandiford, "Educational Psychology," p. 240.

† See "Law of Recency," Sandiford, *ibid.*, p. 200.

sive examinations have caused the faculty to observe defects in course administration as well as in the curriculum. This fact alone justifies their continuance. They should, however, be considered from an experimental point of view and with due humility.

The comprehensive examination should not be an added burden to the student and the faculty. Students taking these examinations should be excused from course finals and from course work during a reasonable preparation period. The faculty committees are faced not only with the problem of judging the capabilities of the student but also of judging the validity of the examinations. This task requires a great deal of faculty time and effort. Adequate study of the problem and a favorable result may lead to the introduction of undergraduate comprehensives in engineering similar to the divisionals used at Harvard University.

Throughout the entire discussion it has been assumed that the aim of the undergraduate and graduate engineering curricula is to train men in the broader aspects of engineering in contrast with training as a specialist in a narrow field. Industry requires men with general training.

The preparation of this paper was accomplished after consultation with many members of the staff of the Department of Mechanical Engineering. Professors E. D. Howe, M. P. O'Brien (present Chairman of the Committee on Graduate Study and Research), J. H. Hildebrand, Mr. J. T. Peterson, and Mr. V. H. Cherry were especially generous with ideas and time.

RATIO OF CHEMICAL ENGINEERING COURSES TO OTHER COURSES IN CHEMICAL ENGINEERING CURRICULA IN TECHNICAL INSTITUTIONS

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A study of the Chemical Engineering curricula in the technical institutions of the United States reveals some interesting and helpful facts. No two curricula are alike either in the courses included, in the number of credits allowed the common courses, or in the relative percentages of the basic, general technical, special technical, and the cultural courses.

These differences are as they should be. A careful study suggests that it would be unwise to attempt to standardize the curricula of the various institutions. Our departments exist primarily to serve the chemical industries in our own areas. Since the types of industries vary in the different parts of the country, the types of the training of the young men should be arranged so that they can most quickly and naturally adjust themselves to the types of work they are expected to do. Naturally the work in an institution in a steel area would emphasize work on metallurgy and metallography, whereas one located in an oil area should include technical and practical courses pertaining to that industry. Naturally also certain of the unit operations should be given more extended study by one institution than by another.

It has, however, become generally accepted by all departments that certain basic courses are fundamental to all chemical engineering training and it is interesting to observe the practical uniformity in number of total credits required for a four year degree and of the almost uniformly balanced ratio in the number of credits in the basic courses mathematics, English, chemistry, and physics. The uniformity in basic courses has come about by the experience and judgment of the staffs of the various departments rather than by an attempt to adjust curricula according to some prescribed formula.

It is more important that a uniformity in principle and purpose be attained voluntarily by the departments than to have an artificial and involuntary uniformity in fact to fit into some arbitrary standard. We are making satisfactory progress in this direction.

Due consideration of course has been given to the pioneer work in 1922 of Dr. A. D. Little in the earlier years of general chemical engineering instruction. But none of the curricula now correspond to the percentages suggested by Dr. Little's committee. Their work indeed was most valuable as pointing the direction of development of scientific chemical engineering instruction.

The data used in the tables are term credits obtained by converting all credits to the uniform basis of the division of the academic year into three equal terms. The first six tables present the actual term credits listed in the various catalogues as nearly accurate as could be computed. The seventh table presents relative percentages of term credits in each group of courses.

Institutions	M. I. T.	L. S. U.	Ala. Pol.	Ga. Tech.	V. P. I.	Lehigh	U. Col.	Princeton
A. Basic Courses								
Mathematics	18	24	30	27.9	24	18	27	22½
English	18	18	12	10.8	21	9	13	18
Chemistry	55½	57	55½	56.1	48	50	48	42
Physics	22½	15	12	5	13	9	15	9
B. General Technical								
Mechanics	9	15	4½	8.5	6	9	9	9
Mechanics of Mat., Str. Materials	1½		4½	3	3	4½	7	4½
Heat Eng.					6	4½	3	4½
M. E. Lab.			3	1.5	2		2	4½
Surveying							3	
El. of E. E.	6	9	12	8	4	4½	8	9
Eng. Draw. and Machine Design	6	3	6	3.5	8		3	12
Shop					3½			
Hydraulics							3	
Slide Rule							1	

Institutions	N. Y. U.	Case	U. Wis.	Armour	Pa. State	U. Minn.	U. Mich.
A. Basic Courses							
Mathematics	22½	27	27	15	28½	25	24
English	9	9	9	6	18	9	16½
Chemistry	42	46½	33	60½	57	60	46½
Physics	15	15	15		24	15	15
B. General Technical							
Mechanics	4½	4½	15	6	12		
Mechanics of Mat., Str. Materials	6	6				4	
Heat Eng.		4½					6
M. E. Lab.		1	4½	3		6	
Surveying		4½					
El. of E. E.	11½	9	9	9	9	6	
Eng. Draw. and Machine Design	9	9	9	10		6	9
Shop			6			6	
Hydraulics						3	
Machine Design							11½

Institutions	Iowa St.	Ohio St.	Cooper Union	Univ. Pa.	Mich. St.	Brooklyn Poly.	Univ. Ill.	N. C. St.	V. P. I.	Purdue	U. Pittsburgh	Mont. St.
A. Basic Courses												
Mathematics	22	30	30	22½	24	27	22½	30	27	27	24	27
English	13	9	6	29	9	20½	9	21	21	15	12	15
Chemistry	54	44	51	50	42	57	52	47	48	48	45	49
Physics	15	15	24	12	15	12	12	12	16	12	15	18
B. General Technical												
Mechanics	12	13	16½		3	12	3	6	6	6	4½	8
Str. Materials		3	6			3	6	3	3			4
Heat Eng.			9	12			4½	6	6	4½	4½	4
M. E. Lab.	1	4			2				2	1½		
Surveying					4							2
El. of E. E.	8	8	9	10½	7		15	6	6	11	9	4
Eng. Draw. and Machine Design	8	10	9	4½	12	9	4½	9	8	9	6	6
Shop	2			3	6			6		6	6	2
Hydraulics					3	4½			3			
Pipe Fitting	1											

	M. I. T.	L. S. U.	Ala. P. I.	Ga. Tech.	V. P. I.	Lehigh	U. Col.	Princeton Univ.
C. Special Technical								
Chem. Eng. Lec.				.2	2			4½
Ch. E. Prac. or Intro. to Ch. E.					8⅔	1½		
Ind. Chemistry or Ch. Industries	17		9		9	7	4	12
Ind. or Org. Tech.				3		12		
Elec. Ch. Processes						3		
Ch. Eng. Mat.							6	
Unit Operations Ch. E. Projects								
Prin. Chem. Eng.	12	10½	4½	6	6	4½		9
Metallurgy, Metallography			3	3		9		4½
Ch. E. Lab.	12	9		4	4	6		4½
Ch. E. Calc.	3	6		2.7	2		2	4½
Ch. E. Design			1½		6		6	4½
Ch. Mfg.								
Pynometry								
Ch. Econ.		3			3	4		
Tech. Anal.		9			3			
Safety Eng.								
Refrigeration							8	
Thesis Research	8							
Colloids			3					
Thermodynamics				3			5	4½
Microscopy							2	
Chem. Machinery							6	

	N. Y. U.	Case	U. Wis.	Armour	Pa. State	U. Minn.	U. Mich.
C. Special Technical							
Chem. Eng. Lec.	6				1½		7½
Ch. E. Prac. or Intro. to Ch. E.			3	7½			
Ind. Chemistry or Ch. Industries	6	9	6		12	8	3
Ind. Org. Tech.		7½	7½				7½
Elec. Ch. Processes	9	4½	7½				
Ch. Eng. Mat.		2½	3				4½
Unit Operations Ch. Projects							
Prin. Chem. Eng.	9	4½	6	16	12	16	9
Metallurgy, Metallography	3		4½		4½	3	
Ch. E. Lab.	4½			16½			3
Ch. E. Calc.	3	4½			3		
Ch. E. Design	3	2	4½	6			4½
Pyrometry			3				
Ch. Econ.		4½					
Tech. Anal.	4½	13	3	15		3	
Thesis Research	7½	3			9		
Thermodynamics	12		15				
Tech. Elec.							12

C. Special Technical

	Iowa St.	Ohio St.	Cooper Union	Univ. Pa.	Mich. St.	Brooklyn Poly.	Univ. Ill.	N. C. St.	V. P. I.	Purdue	U. Pittsburgh	Mont. St.
Chem. Eng. Lec.	3	3	9	3	3				2	1½	1½	
Chem. E. Prac., Intr. to Ch. E.	2				3			3			3	
Ind. Chem.	9	6		4½				9	6			10
Ind. or Org. Technology	4		6		6		6			9	6	
Electro Ch. E.		4			3			3				5
Water Purification								3				
Ch. E. Mat.	2		3	3	5			3				9
Unit Operations, Prin. Ch. E.	8	15	34½	9		11	25½	9	15	22½	14½	10
Metallurgy, Metallography	5	8		3	9	3			6	4½	3	
Ch. E. Lab.	9			6	11			9			15	7
Ch. E. Calculations	8		3	7½				3			4½	6
Chem. Eng. Design	6	2		2		3				6		
Chem. Mfg.												
Pyrometry					2					3		
Ch. E. Econ.												
Tech. Analysis	3				6	3			7			
Seminar				6					6			
Thesis—Research		14	7½		10	12	3				3	9
Colloids				3								
Thermodynamics			9	4½	6	6	3		4½	4½	6	
Chem. Machinery												
Technical Electives		2		3			10½					
Chem. Eng. T. Prin.	8										6	
Control Methods											3	

Basic Courses

Every curriculum includes instruction in the basic courses mathematics, English, chemistry, and physics.

In Mathematics the average number of term credits required is 24.94. The range is from 15 term credits to 30. This average may not be considered altogether advisable for every curriculum because in some of the institutions tabulated the students are prepared apparently to start higher in the mathematics courses than in other cases. In this list it will be observed that a few require less than 20 term credits. All curricula require mathematics through calculus.

In English an average of 13.9 term credits is required. This average is lower than the usual requirement because some curricula allow a choice in the sophomore year between English and a modern language. The range of requirements in English varies from 6 to 29 credits.

The average number of term credits required in chemistry by these institutions is 49.7.

This average is high because a few institutions are out of line with the usual set-up of most of the institutions. If these unusually high ones are not averaged the result is 47. This number is in line with the general practice.

The average requirement in physics by these institutions is 13.9 term credits. Some of these institutions are out of line. The range is from 5 credits to 36 credits but most of them are between 9 and 15.

Of the general technical courses engineering drawing, mechanics, and elements of electrical engineering are required in practically all of the curricula.

In drawing an average of all the schools is 6.65. This is another example of the inadvisability of trying to set up an average. The range is from 3 to 12, with many assigning 8 or 9 hours to drawing. In several cases applied drawing or design work is done in the home department in machine or plant design.

In mechanics the average is 7.5. The range is from 3 to 16.5.

In elements of electrical engineering the average is 7.7. The range is from 4 to 15.

Of the twenty-seven institutions, seventeen require strength of materials (in some cases called mechanics of materials). The range is from 1½ to 7 with the favorite number of 3 to 6.

	M. I. T.	L. S. U.	Ala. Poly.	Ga. Tech.	V. P. I.	Lehigh	U. Col.	Princeton
D. Cutural								
Military Sci.	18	6	12	3	9	12		
History	4½	9	6					
Phys. Ed.	3		¾		1		3	
Foreign Language	4½	9+9=18	18	9	13½			9
Economics	9			4		9		9
Sociology								
Accounting								
Mineralogy-Geol.			4½					
Bus. Law							3	
Econ. History								
Business Course							3	
Sciences								
Elective Gen'l			24		9	18	18	9
Library		1½						
Psychology			3					
Bus. Org., Prin. Ind. Org.					3			
TOTAL	227½	211½	223½	242	210	190	206	199

	N. Y. U.	Case	U. Wis.	Armour	Pa. State	U. Minn.	U. Mich.
D. Cutural							
Military Sci.	6				9		6
History		9					
Phys. Ed.					6		
Foreign Language	18	9		6	18	12	
Economics		4½	4½				9
Sociology				4½			
Accounting							
Sciences							
Elective Gen'l		13½	18	4½		9	9
Elective Tech.	9						
Library							
Psychology							
Bus. Org., Prin. Ind. Org.							
TOTAL	220	227	213	225	224	191	204

	Iowa St.	Ohio St.	Cooper Union	Univ. Pa.	Mich. St.	Brooklyn Poly.	Univ. Ill.	N. C. St.	V. P. I.	Purdue	U. Pittsburgh	Mont. St.
D. Cutural												
Military Sci.	6	6		No credit (12)	6		No credit	12	6	6¾	3	6
History....						6						
Phys. Ed...		4		(6)		12		6	1			3
Foreign Language			6	6		15	12			9		
Economics..			3		6	6		9	6	3	7½	6
Sociology...			3		3							
Accounting.					3			3				
Mineralogy-Geol.....		6						6				
Bus. Law...			3		3			3	3		3	
Bus. Course.					3							
Elective Gen'l	9	12			3	6	4½	18	18	18	7	
Library....												
Psychology.											1½	
Bus. Org....												4
Bacteriology					3							
Heat Treatment.....					3							
Hygiene....							3					
TOTAL.	210	227	223½	218	218	222	196	242	222	228	213	214

Fourteen require heat engines ranging from 4½ to 12 with about 6 as average.

Fourteen also require M. E. Lab. ranging from 1 to 6.

Ten require definite shop courses in addition to the practical departmental shop work presumably required of all.

Of the special technical chemical engineering courses listed in the various curricula it is observed that all require the fundamental course called variously principles of chemical engineering, unit operations, etc., 4½ to over 20 terms credits. All require the associated process course variously called Industrial Chemistry, and industrial inorganic, or organic Technology, varying from 3 to 17 term credits.

All also require chemical engineering lab. included in the number of listed credits of the corresponding class course or as a sepa-

rate chemical engineering laboratory course. Practically all require separate courses in chemical engineering calculations and in stoichiometry.

In the cultural courses nearly all provide for military training and physical education either with or without credit. Foreign language study is either required or is available among the general elective courses. Economics is generally required. The following table presents the relative percentages of term credits provided in the Chemical Engineering curricula of thirty institutions in chemistry, chemical engineering, physics, mathematics, other engineering, cultural, other sciences, and electives.

Institution	Chem.	Ch. Eng.	Phys.	Math.	Other Eng.	Cultural	Other Science	Electives
N. C. State	19.60	17.80	5.12	11.50	16.50	20.50	1.28	7.70
Univ. of Mich.	20.00	21.45	7.15	11.40	18.55	11.45	0.00	10.00
Univ. of Iowa	25.00	15.20	7.10	13.00	18.70	21.00	0.00	0.00
La. State Univ.	22.10	20.10	8.10	10.70	16.20	18.80	0.00	4.00
M. I. T.	24.70	25.08	10.90	5.70	13.73	17.05	0.00	2.84
Ohio State U.	14.80	20.50	7.18	14.30	32.50	4.79	0.00	5.85
Case Sch. App. Sc.	25.40	18.00	7.00	9.60	18.00	20.80	1.10	0.00
Univ. of Ill.	21.70	15.70	6.90	11.40	16.70	12.20	0.00	15.40
Univ. of Wis.	14.40	26.20	6.60	11.80	25.50	5.70	0.00	9.80
V. P. I.	21.70	12.60	7.02	10.50	21.60	16.00	0.00	10.50
Mont. State	26.40	17.80	8.60	13.00	19.30	14.90	0.00	0.00
Univ. of Mo.	21.35	7.35	7.35	14.70	25.70	16.20	0.00	7.35
Univ. of Miss.	27.50	22.50	6.90	13.75	15.60	9.65	0.00	4.10
Iowa State Col.	25.70	23.00	7.00	12.20	18.20	8.80	0.00	5.10
Lehigh Univ.	27.60	17.10	10.50	7.90	13.80	19.10	0.00	4.00
Univ. of N. C.	23.20	18.30	4.30	11.60	20.00	19.00	0.00	3.50
Oregon State	26.50	18.20	5.90	13.20	10.80	14.70	0.00	10.80
Univ. of Texas	27.00	12.20	9.20	9.20	18.20	19.50	0.00	0.00
Ga. Tech.	25.40	13.05	8.35	12.80	15.40	25.00	0.00	0.00
Univ. Florida	25.70	13.20	6.90	11.10	20.10	18.70	0.00	4.10
Univ. of Va.	26.50	15.20	7.80	11.80	17.80	20.90	0.00	0.00
Brooklyn Poly. Institute	29.70	18.80	6.60	10.30	14.80	17.50	0.00	2.30
Armour Inst. of Tech.	23.40	22.70	7.20	12.60	15.30	18.80	0.00	0.00
Purdue	19.60	19.20	4.90	11.10	19.50	22.60	3.10	0.00
Carnegie Tech.	24.60	18.20	7.08	8.25	23.00	15.70	1.30	1.77
Tulane Univ.	21.80	20.20	9.15	11.00	20.15	15.90	1.80	0.00
Texas A. & M.	26.70	8.20	5.50	15.10	15.10	16.40	4.80	8.20
Auburn Poly.	23.00	10.20	5.05	12.70	11.80	25.20	1.95	10.20
Univ. of Ala.	19.15	15.95	9.28	13.25	19.85	12.58	1.98	7.96
Okla. A. & M.	19.72	19.81	6.95	12.50	22.95	14.60	0.00	3.47
Average	23.10	17.75	7.25	11.60	18.55	16.50	0.60	4.65

In this study it would be profitable and proper to include the data from the other institutions. Unfortunately all of the official bulletins for 1936–37 were not available in time for this compilation. Data have been compiled from the former published information. However two difficulties exist: Several institutions are imposing certain requirements for the inclusion in the curricula of the various departments prescribed number of the so-called cultural and social courses, thereby placing physical limits on the opportunity for balanced ratios. This fact is the more apparent by a consideration of the wide variation in percentage of "cultural courses" observed in the percentage table in which the range varies from 4.79 per cent to 25.20 per cent. All of us naturally give thoughtful consideration to the doctrine of "changed conditions," but we also realize that a certain amount of fundamental training is necessary to a well equipped chemical engineer, and that there is a physical limit to the possibility of including many general courses in a four year curriculum which in the nature of things must include all the fundamental engineering courses studied by any engineering students and all the pure chemistry courses studied by regular chemistry students as a background for professional chemical engineering courses. In the percentage table it will be noticed also that "elective" courses provided by the discretion of the staff or by the general faculty decision varies from 0 per cent to 15.40 per cent of the total courses in the curriculum.

It will also be observed that the percentages of the five fundamental subjects listed on the percentage table vary inversely with the variation in percentages of "cultural" and "elective" courses and also with the preponderance given to certain types of subjects. In certain cases the excessive percentages given certain courses makes it impossible to arrange a balanced outline of studies. Notice for example how the wide range in chemistry varying from 14.40 per cent to 29.70 per cent together with the cultural and elective percentages causes the chemical engineering requirements to vary from 5.20 per cent to 26.20 per cent, physics to vary from 4.30 per cent to 10.90 per cent, mathematics from 5.70 per cent to 14.30 per cent, and other engineering courses to vary from 10.80 per cent to 32.50 per cent.

The very definite trend in revision of curricula appears to follow the middle course and to avoid or correct the former tendency to over-emphasize any subject or group of subjects. So much is expected to-day of a young chemical engineer that it seems unfair to him not to have the proper balance in his educational background.

The fact also weighs upon us that our profession is comparatively new and that perhaps more rapid and revolutionary changes are in progress in our field at present than in any other. Therefore our curricula cannot become static or uniform. No percentage formula should be attempted as standard because of these facts. We can only keep our ears to the ground and be alert to formulate progressive curricula as far as possible to equip our graduates to be as broadly educated as possible consistent with the ever increasing requirement that they may obtain as sound technical training as is possible to attain within four years of academic training.

We are consciously in the process of training men for a definite profession to contribute their share to the material welfare of people and to convert raw materials into useful products in the largest possible yield, of the highest quality, at the minimum cost, or to provide the things people need at a cost they can afford to pay. We also wish to train these men to be substantial and successful citizens of their various communities. In this effort we are guided by the experiences of the pioneers in this important branch of engineering, by the requirements of the industries which employ our graduates, and by the wishes of the men who have their own lives to live in a profession which is doing much for human comfort and progress.

CHANGING DEMANDS ON THE TECHNICAL GRADUATE

By BERNARD LESTER

Lecturer, University of Pittsburgh; Assistant Sales Manager, Industrial Dept., Westinghouse Electric and Manufacturing Co.

We cannot over-emphasize the important part our technical schools have played during the last few decades in providing and training the talents which have been largely responsible for our material progress. Technical men have revolutionized accomplishments in the fields of transportation, public utility service and mechanization in connection with construction, mining, manufacture and agriculture.

As one who has been in close touch with industry and has been in contact with a large number of young technical graduates employed by many companies, I firmly believe that there exist further possibilities for the training of technical students toward greater usefulness, in the face of changing conditions.

In most industries dealing with technical products and processes, we are witnessing some fundamental changes. These changes create new demands upon the technical graduate and the indications are that they will be more pronounced as time passes.

Even the casual observer of events in industry during recent years has noticed the mounting investment in machinery and equipment utilized in our major industrial activities—manufacture, mining, transportation and public utility service. Not many years ago, the land, the factory buildings, the inventories and liquid funds formed almost the entire assets of a company. To-day, the largest single item of value is usually machinery and equipment necessary to manufacture products or render service.

Our technical skill, in past years, has been largely devoted to the invention, design, construction and operation as related to technical products. We have devised remarkably ingenious equipment which has been combined with cleverly engineered manufacturing processes. We have learned well how to design and operate machinery and equipment with a high productive value and a low production cost.

At the start of the present decade the pendulum of demand, which had swung, with little interruption, in the direction of an attempt to meet the supply, suddenly stopped and started the other way. Problems were no longer those of production, but became

those of distribution. Eyes were suddenly turned to the market. How to develop markets and to devise better and more efficient means of reaching them became problems of singular importance. The customer, rather than the product itself, assumed proportions of great significance. We knew how to engineer the product and its manufacture, but we found we did not know how to engineer its distribution.

Such a situation as this has had a very profound effect upon the engineer:

First—the viewpoint of the engineer who designed apparatus had to undergo a change. Instead of focussing his attention on the apparatus only as an operating unit, he must now give greater cognizance to it from the viewpoint of the purchaser. Our social relationship in regard to machinery and equipment has changed. Apparatus has finally been admitted to society, so to speak, and has, in the last few years, had its "Coming-out Party." It has become a companion of man. He comes in contact with it wherever he goes—during his work and during his recreation.

This being the case, technical products must not only perform the service for which they were intended, but they must possess additional attributes which make them acceptable in human society;—convenience, cleanliness, safety, quiet operation and many others are necessary. More recently, beauty of shape and color have become actual requirements in order to attain customer acceptance. We are developing a style and a taste when it comes to technical products and we find thrust upon an engineer the solution of problems calling for a knowledge of customers' markets and economy in distribution.

Secondly—with the technical processes of industry increasing in variety and also becoming more highly individualized, the engineer's talents become of greater demand in fields of distribution where his abilities are exercised in studying customers' problems and arriving at a solution of them through the application and use of engineering products made and sold. A broader appreciation of the customer market, combined with an intimate knowledge of the problems of the purchaser of engineering products, has recently become of outstanding value to many of our technical graduates. Thus the application of practical economic principles becomes more necessary each day in the work of the engineer.

Fifteen or twenty years ago, many of the leaders at the head of companies engaged in the production and distribution of technical products were distinctly technical men. One has only to look about to-day to see that most of such organizations are guided by engineers who have applied engineering methods to commercial

situations. Though technically trained, success has come largely through their ability to understand customers and markets and how best to serve them economically and well. I think it is true that each year a larger number of our technical graduates become thrown in closer contact with problems relating to markets and methods of distribution. These problems call for knowledge and training in the fundamentals of distribution as related to technical products.

There still exist many erroneous notions in regard to selling. One technical graduate recently made the statement to me that he knew he would never make a salesman "because he lacked that breezy manner which all salesmen must have." The days of the breezy, smart, slap-stick salesman have gone. Engineering selling to-day is a serious matter and although personality in the individual can add much to his success, the man who will attain a sound and continued success is the one who knows the technique of the product to be sold, the character of the market to be met and above all, is able to interest himself in his customer's problems and their solution. Such men are not born, but they may be developed through training.

The training required for sales engineering differs pointedly from the training required for merchandising commodities. An entirely different set of principles governs buying and selling in the capital goods field involving technical equipment. In almost every city of the country some sort of instruction is available in commodity marketing, yet to-day, in only a very few of our technical schools is there available to the students any comprehensive instruction in the principles involved in the distribution of engineering products. Many of our technical schools have attempted to satisfy these needs with broad courses in economics and psychology, the merits of which cannot be questioned. Others have attempted to meet the need by offering courses in commodity marketing. Neither furnish adequately the training required by a practical application of the principles of economics and psychology to the large field of technical products.

Some observers have stated that training in distribution of this sort should be left entirely to the employer. I cannot agree with this, for many employers do not have the facilities for conducting such instruction. The subject is fundamental and the young graduate should be equipped to step into the study of the specific product his employer makes or sells and the relation between it and the employer's organization and methods of operation, and the market. Many young technical graduates have told me that their training has left them entirely at sea as to the relationship between

the product, the market, and an organized method of reaching the latter. As I see it, those industries dealing with technical products and service are looking for men, not only well grounded in technical principles and economic law, but also in the principles of distribution as concerning this vast and rapidly growing investment in capital goods for purposes of production.

Obviously, our educators are continually harrassed by business men who suggest additional courses of instruction. Often such suggestions are the pet subjects of the individual. Under such conditions I can imagine the difficult problems that come before our educators. These observations may, however, serve to emphasize and throw some light upon a problem which I believe is a very real one to manufacturers of technical products today. It deserves further consideration, I believe on the part of the large number of technical educators who have on their shoulders the responsibility of training men for industry.

THE TAU BETA PI ENGINEERING EDUCATION SURVEY

A survey of a number of aspects of engineering education was recently completed by the members of the Massachusetts Beta Chapter (Mass. Inst. of Tech.) of Tau Beta Pi. The results of this study are not only of interest because the entire undertaking was conducted by undergraduates but because of its value in reflecting the considered opinion of the abler students of engineering in a representative group of institutions. The following summary of the results of the survey is published in the JOURNAL with the purpose of acquainting a larger number of engineering teachers with the views of the students on the questions considered than would be reached by *The Bent* of Tau Beta Pi in which the results originally appeared.

The survey was conducted by means of a questionnaire which was circulated to more than one thousand active members of the fraternity, chiefly seniors. Four hundred thirty-nine replies were analyzed and tabulated. The results may therefore be taken as the concensus of a representative group of students of considerably better than average ability enrolled in all the principal engineering curricula. The questions of the questionnaire form were answered by checking from a prepared list of responses. In certain instances "yes" or "no" replies only were given. In others an order of preference among several alternatives was given. In some instances a large majority of replies indicated the same response; in others the preponderance of affirmative or negative answers was less marked. The tabulation of responses (too extensive for publication herein) shows an excellent method of summarization. The following generalized statement of the results is arranged under the same headings as were used in the questionnaire itself: Study Procedure; Instruction Procedure; Qualifications of Instructors; Orientation to the Professional Feld; Determination of Scholastic and Professional Ability; Stimulation of Professional Interest; Miscellaneous.

THE RESULTS OF THE SURVEY

I. STUDY PROCEDURE

Problems

Types—The majority of those reporting like, above all, problems illustrating the practical application of theory. They also prefer (not in order of preference):

1. General problems covering many phases of the course instead of particularized problems.
2. To do problems at home on their own responsibility.
3. Problems with correct answers given.

They do not like:

1. To solve problems by teams (each doing separate part of comprehensive problem).
2. To solve problems in supervised study groups with instructor available.
3. To have correct method of solution shown.

Solution—Those questioned would prefer that the instructor present the solution in class rather than the students. Wrong problems are to be repeated by the student until the principles of solution are demonstrated correctly but not necessarily repeated until the correct numerical answer is obtained. This group of students values the various factors in the solution in the following order of importance:

1. Recognition of essential principles involved.
2. Correlation of previous knowledge with the principles involved.
3. Ability to show clearly the reasoning and methods used in arriving at the solution.
4. Mathematical ability.
5. Mathematical accuracy.
6. Neatness of presentation.
7. Speed.
8. Memory.

Textbooks

Use—Those reporting are emphatic in their belief that textbook reading should be given in many short assignments and not in a few lengthy assignments. Text exercises should be used as a supplement to class room instructions and lectures. The question whether or not they should be used as a main source of information was not decided. These students also find the text instead of lecture notes more useful in solving problems. A slight majority will puzzle through a difficult mathematical demonstration in the text while the others, in almost as large a body, rely on class room instructions to get these demonstrations. As a general rule they do not prefer texts written by their own instructors. One reason for this is that they feel that instructors using their own texts follow them too closely, to the exclusion of other valuable material.

Attributes—In order of importance.

1. Clearness of presentation of theory.
2. Illustrations of definite, practical applications of theory.

3. Good lists of illustrative problems with type solutions.
4. Informal, readable style.
5. Complete and easily used index.
6. Large quantities of information presented.

II. Instruction Procedure

Class Room Recitations

This group prefers a class of less than twenty students and it *must* be conducted in an informal rather than formal manner. It also has a strong feeling that students should add to the discussion whenever they feel they can add to the information or clarify the presentation, and not only when questioned. All the problems should not be recited upon but only those which caused difficulty for the majority of students. In general, the members of this group do not feel that they have been held back by those of lesser ability in the recitation sections.

Lecture Instruction

A more personal lecture, delivered to a small group by a recitation instructor, is preferred more than the large sections addressed by a trained lecturer. Lectures which explain only the more difficult parts of the text or subjects not given in the text should be used instead of those which follow the textbooks closely. Although most students do not have excessive difficulty in following the reasoning processes of the lecturer, at the same time retaining the facts presented, they would appreciate more consideration of this difficulty on the part of lecturers. The majority of students take an outline of the lecture for filling in from memory rather than trying to cover the talk completely, and about one sixth take no notes at all. For note-taking a slight majority would like a knowledge of shorthand. In all cases the students would appreciate greatly a mimeographed, brief outline of each lecture, prepared by the instructor and distributed to each student before the lecture.

Elementary Laboratory Instruction

There is a decided feeling that laboratory work is *not* overemphasized. The laboratory procedure desired is this:

1. Laboratory problems should be taken from a manual, if possible, or else suggested by the instructor rather than by the student himself.

2. The technique for solving the problem should be given by the instructor or by a manual, but should not be developed entirely by the student.

3. There should be close supervision by the instructor and his help should be available when needed rather than allowing the student complete independence in the laboratory.

4. It is important that the student assemble the apparatus whenever possible.

5. If a group does the laboratory assignment it should work collectively but each member should make *all* the calculations rather than having each responsible for a section.

6. Laboratory reports should contain the self-estimate by the student of the accuracy and reliability of the work.

Advanced Laboratory Instruction

The procedure for advanced laboratory work differs from the above in certain ways, mostly toward making the student more independent in the laboratory. There should not be close supervision by an instructor but he should be available to render help when needed. Problems should be suggested by the student or by the instructor and the technique for solution should be developed, insofar as possible, by the student. Other points in the procedure are about the same.

Class-room Quizzes

Class-room quizzes should be scheduled about every two weeks. There is a decided preference for quizzes and examinations in which texts and notes may be used, one reason for this being that it is felt that memory requirements in quizzes in engineering courses are unnecessary. However, it is not advisable to allow the instructor to give advice and directions during an examination. It is also highly desirable to have a choice of questions in quizzes.

Quizzes should be graded on the following percentage (only these four factors were suggested in the questionnaire—there may be others):

Correct method	60%
Correct numerical answer	20
Neatness	10
Ability to complete quiz within allotted time	10

Furthermore, it is felt that "cribbing" in quizzes seriously detracts from their effectiveness.

III. The Qualifications of Instructions

Characteristics of a Good Teacher

In order of importance:

Aspects of Instruction Which Should be Emphasized by Teachers

In order of importance:

1. Presentation of general principles of the subject-matter.
2. Emphasis of the relation of theory to practice.
3. Instruction in the methods of handling the mechanics of the course.
4. The organization of routine work, such as problem solution.
5. Emphasis of the relation of his course to other courses.
6. Preparation to pass the final exam in the course.

In General

Engineering teachers do not lack pedagogical principles of the normal school standard, as they are often accused. Good teachers are more essential in the freshman year than in any other period. In general, freshman instructors do not appear bored with the laboratory work, nor preoccupied with research work, and they do have ability in handling young students. The first and second year studies were not considered of more value than those of later years in determining success in engineering.

Bases for the Advancement of Instructors in Order of Importance

1. Their ability as teachers.
2. Technical ability.
3. Accomplishments in research and other professional work.
4. Seniority.

Student Instructor Conferences

It is felt that real, definite, and sufficient emphasis is not placed on the student-instructor conferences, and students do not take full advantage of the opportunities offered by those conferences. Possible uses for these conferences in their order of importance are:

1. Ironing out the difficulties in course instruction.
2. Instilling enthusiasm in the student.
3. The presentation of complaints.
4. Arriving at better understanding between teacher and students.
5. Suggesting avenues of student research.
6. "Bull Sessions," discussions not particularly related to the course.

IV. Orientation in the Professional Field

Choice of Professional Field

Ninety per cent of those answering believe that general interest in the subject influenced their choice of a professional field. The influence from aptitudes shown by previous experience (by hobbies, proficiency in science and mathematical courses in high school, etc.) was felt by almost as many as the previous one. Neither family influence, advice given by friends, by registration officer nor by teachers was considered by the majority to have influenced their choice of fields. Both reading and personal analysis of the engineering situation affected a little less than half of the students. The reputation of the particular department influenced about 25 per cent in their decision, and the proximity of the school was taken into consideration by about 40 per cent.

As many as 75 per cent had selected their course before entering school and they believe it was wise to have decided beforehand. Only 25 per cent have changed their course since entering and some 90 per cent plan to pursue professionally the course they are now taking providing the chance is offered.

Graduate Study

It is overwhelmingly believed by these students that graduate study is valuable. The following reasons were given in order of importance:

(*a*) They feel that they need extra preparation for greater professional effectiveness.

(*b*) Graduate study is necessary for the achievement of scientific proficiency.

(*c*) Graduate study brings prestige and greater earning power.

There was no decisive answer one way or the other whether graduate study was considered valuable as a depression stop-gap.

Professional Guidance

Only half of those questioned felt satisfied with the opportunities for professional guidance offered by their schools. To improve this situation they suggested that there be courses in vocational guidance with closer intimacy between student and registration officer. It was also felt that up until the Junior year a student should be free to change his course without loss of time.

V. Determination of Scholastic and Professional Ability

Computing Term Grades

The following percentages were considered to be fair bases for computing term grades:

Class room quizzes	25%
Final examination	25
Recitation record	15
Laboratory record	15
Home problem record	10
Instructor's estimate of student's ability	10
Attendance	0

Almost all of this group would not prefer just one passing mark, denoting satisfactory completion of the requirements. To a lesser degree, they do not feel they would get more benefit from their work if not preoccupied with obtaining high marks. Along this same line they feel that it is unwise for school authorities to stress scholastic competition. To a slight extent they think the desire to obtain good grades leads to cribbing and other forms of petty dishonesty.

They also believe that men should be segregated in recitation sections according to their scholastic ability so that the instruction may be better suited to their mental speed and general scholastic aptitude. They emphatically state that persons who receive good grades are not looked down upon in their schools as "grinds" but rather are generally respected.

Comprehensive Examination

The general feeling is one of approval for the comprehensive examination. Ninety per cent believe it would be a fair measure of a student's engineering ability (*i.e.*, reasoning power, judgment, correlation of facts) and also a fair measure of his general knowledge. There is likewise a strong belief that it would be good preparation for problems which arise after graduation, a record for prospective employers, and a stimulus to interest on the part of the student. Furthermore, it would be an incentive to do good work during the term, an incentive to do outside reading and other related but not required work. They do not think a comprehensive examination would provoke cramming and tutoring beforehand or temptation to crib on the examination.

VI. Stimulation of Professional Interest

Stimulation

As many as 40 per cent of the group feel that engineering teachers fail to stimulate students with enthusiasm for their profession. A large majority think that professional and honorary societies should assume the responsibility of stimulating this professional interest. About 30 per cent believe that extra-curricular activities, such as management in athletics, publications, etc., detract from this interest because they compete with studies for the student's time.

A very large majority stated that informal student-discussion groups, organized and run by students, in which professional problems of interest may be discussed, are both feasible and desirable.

Placement

About 60 per cent of the group reported that their schools offered an effective organized program of placement guidance for seniors and graduate students. There was even greater response that they would welcome advice on how to make contacts, write letters to interviewers and prospective employers, and undergo interviews. However, they did not think the school should assume the responsibility of placing the students. Only 20 per cent stated that the present depression (1930–1935) dampened their interest in engineering.

General

In summary, some 60 per cent of those answering felt that their engineering education fitted them for entry into the keen competition of the present situation in engineering. Many, however, felt unprepared in practical experience, and others desired to have taken Public Speaking which was not included in their curriculum.

Only 45 per cent of them felt adequately trained to express themselves easily in correct, clear, and forceful English, both spoken and written.

Many of those who took time to comment felt that engineering courses should be longer than four years—preferably five or six.

VII. Miscellaneous

Study

Most of this group have worked out some satisfactory method of utilizing their time so that all ordinary activities are taken care of.

Nevertheless, a large group feel rushed most of the time. Slightly less than half of these students study with the radio on, while others reported that they were most frequently disturbed by talking. A small majority study best when alone.

A fair majority of those reporting have taken courses in which the personality of the instructor seemed more important and valuable than the course he taught. This experience added greatly to the appreciation of their engineering training.

College Education

Those reporting estimate the value of the various parts of their college education as follows:

Ability to think logically and with concentration	25%
Professional training	20
Ability to work	15
Social training for effective participation in activities of organized society	15
Extra-curricular activities	10
Professional connections, in faculty and among classmates	10
Good times	5

They consider the following factors to be stimuli to scholastic success:

Personal satisfaction	25%
Interest in work	25
Natural ability	20
Means of obtaining professional success	15
Competition of classmates	10
Few outside interests	5

In Conclusion

Eighty-eight per cent of those answering the questionnaire thought that student opinion should have an increased rôle in the determination of collegiate policy. About 80 per cent felt that this questionnaire fulfills its object, *i.e.*, to determine student opinion on certain aspects of engineering education so that recommendations for improvements may be made.

GRADUATE STUDY IN ENGINEERING SCHOOLS

By E. A. HOLBROOK,

Dean, Schools of Engineering and Mines, University of Pittsburgh

I raise seriously the question as to whether or not much of the so-called graduate study in the several branches of engineering, as conducted in our schools and departments of engineering, has been worth the time and effort given to it. It is conceded that graduate study in mathematics, in the sciences, and in considerable engineering theory is best carried on in the more or less routine manner of a campus. It is agreed that vital advances in engineering have been possible only because of college laboratory research. It is right that these graduate workers should receive advanced degrees as one reward of their efforts. Yet I do resent the prevalent notion that this is the only kind of engineering advance that can fit into a college program. Only the other day, I heard of a college that refused to consider for advance credit, a certain research that was to be carried out in a series of plants situated from 10 to 50 miles from the campus. The college authorities said that work of this kind would not meet the residence requirements of the institution. So far as real engineering research and progress are concerned, it appears time to change those residence requirements. In trying to give a scholarly and graduate appearance to our engineering departments, we have struggled to make graduate scholars out of thousands of boys who ought to have been at work in industry. We have unsettled many men by giving them a distorted picture of the worthwhileness and applied value of graduate school engineering study. We have let them fuss around with equipment not suitable for investigations of a graduate calibre. We have been content to make graduate engineering work an imitation of liberal arts graduate work.

Are we teachers of engineering getting ashamed of our academic position with our general paucity of degrees, and are we imitating our liberal arts brethren by forcing our young engineers and instructors into a single path for professional recognition—the path leading to advanced degrees? Until 25 years ago, a trained engineer was one who had graduated from an engineering course with a Bachelor of Science degree after four years of study, and who had then put in from five to ten or more years, either in practice of his profession, or in positions in industry for which

his college training fitted him. Industry and practical work were the firing lines of the profession, and college training only the background and foundation. It always has seemed to me that the great glory of the engineering profession was that we could lay our foundation best at college, but we did not know what engineering responsibility was all about until we had to give a decision on the job that made us or broke us; until we had to meet the payroll on Saturday night; or until we had to submerge ourselves for the good of the organization. Those were the great tempering agents of the engineer, and for the majority, still are today.

As for the older generation of engineering teachers, they were mostly men with but a single college degree, but with an engineering background that made them engineers, and a term of teaching that had mellowed them, so that they understood boys. Think back to your own great engineering teachers. Did you love and respect them for their wealth of degrees, or because they were kindly men, with a seeming wealth of experince and common sense and that indefinable ability to teach? It was about 1910 that the picture began to change, especially in engineering schools that were a part of universities. Somehow university presidents began asking how many degrees the prospective engineering teacher possessed. The president had only one yardstick with which to measure an educated man, the yardstick of liberal arts. The average university president never has understood that engineering is a different sort of education, a compound of the college classroom with high accomplishment in the field, and that an engineer with several years' background at Boulder Dam might be better fitted to teach civil engineering than one with a Ph.D.

Did you ever consider what may be the great weakness of the liberal arts tradition as applied to engineering education? It appears that it tries to produce scholars with graduate degrees, whose outlet is the teaching of a new generation of students, the cream of whom will become teachers to teach a new generation, and so on ad infinitum. The ordinary student who takes the courses is a by-product, the main product is the small minority who will go on to higher degrees, and carry on the work of teaching a new generation of teachers. It is possible that this liberal arts tradition is right and the only way to carry on the torch of Scholarship. It may be right that the engineer who wants to teach should be forced into the groove of productive scholarship through the acquiring of advanced degrees. Perhaps the time is close at hand when the engineer, to gain recognition in his profession, must have an M.S. or a Ph.D. earned in course. However, I am sure that engineering is a particular kind of an education, not necessarily like liberal arts, and a kind that will be the better for

hewing its own path into graduate study and professional maturity, as it already has done into undergraduate college work.

I have been connected with five institutions of higher learning. There is surprisingly little difference among them, in objectives, policies, or standards. About the same type of boy attends each one. I am convinced that without exception these boys, if they really wish to be engineers or to follow engineering methods, ought to obtain a four year undergraduate foundation in college, and then go to work and find out what it really is all about. It is an old statement that college is an unreal and make-believe world, but I repeat it for the emphasis it may give to my belief—that after four years in college the young man ought to get a job in or around engineering. This job or position ought to continue from one to three years. Frankly, I would hesitate to admit a B.S. in engineering to graduate courses until he had, as a part of his education, that finite touch with the world of reality in engineering that can only come from being a part of it.

After a year or two in practice, the young man knows well what he wants. For the great majority, college and thoughts of formal graduate study are a memory. He is digging into his job, becoming proficient, becoming a specialist, working and studying in his own field. He has or is about to assume family responsibilities. A small minority will want to enter teaching or will know that they need additional mathematics, economics or engineering. Included in the group are those who now know that they will be happy only in research or advanced design. This group ought to form an attachment, full or part time, with some educational institution that can offer them direction and visible rewards of achievement through graduate study and degrees. What I protest is the idea that an engineer can become scholarly and proficient in his specialty only by ordinary graduate college courses. Let us picture two students who have just finished their undergraduate work, and who want to engage, say, in tunnel construction. *A* takes one or two years in graduate study; *B* goes to work immediately after graduation. If *B* is willing to study by himself in his specialty, *A* never will catch up with him. Furthermore, within two years, *B* will know more about tunnelling than the average professor. Do you not see that this is the particular glory of engineering, in being, not a liberal arts tradition nourished by generations of scholars, not a pure science tradition built up in the laboratories, but a combination of both, to which is added an art of its own; an art that seeks perfection through doing, and not alone in telling about what somebody else is or has been doing?

Some six years ago a liberal arts professor at a large Ameri-

can university said to me "The engineering college at our university is asking for a large expansion of program in the graduate school. Some of us on the program committee have wondered if there were enough content in engineering to justify much graduate study!" For the benefit of our non-engineering friends, let me say that graduate work in engineering is without limit, and the type of mind needed to be successful in engineering graduate and research work is not inferior to the mind working in the older fields of learning. It is, or at least ought to be, a different type of mind, and we ought, therefore, not to approach our objectives by the same path as they do.

Open a catalog of almost any engineering or mines school and note special class and laboratory facilities offered for a Master of Science degree and perhaps for a Doctor of Philosophy degree. If a student takes 24 hours of classroom work and six hours for a thesis, he has a Master's degree in one year. This may be followed by two years further work with about 50 more credits in classroom and thesis for the Ph.D. or equivalent degree. Most of the methods and courses are continuations of those used in undergraduate work. We may call the graduate classes seminars, but they still continue in many cases the forced feeding methods common in undergraduate work. Our methods and records emphasize the qualitative side of study, rather than the quantitative. We give a graduate degree when the student has finished six bushels of graduate research in our laboratory! The other day I listened to a scholarly discussion (among scholars in a non-engineering field of learning) on how lengthy a doctor's dissertation should be! Last year I read a short graduate engineering thesis called "An Investigation of Stresses in Sucker Rod Joints," carried on outside the college, which perhaps was more valuable than many other theses twice as long.

Let us also consider whether or not an engineer can become scholarly simply by additional graduate work in his own specialty. It appears that just taking additional courses, say in mechanical engineering, is a poor way to earn a degree of Master of Science in that field. Graduate study years ought to be the time when a student will enjoy giving breadth to his education by taking considerable work in other fields of learning. I am sure that all graduate engineering students ought to have more background in economics for example, or in any one or two of a dozen other non-engineering fields of learning. Perhaps in this way we best can broaden engineering.

I ask you, how many positions are there in the mining industry that would justify a young man taking three years in graduate study within a university? Nine mining companies out of

ten would be prejudiced against the young Ph.D. In other branches of engineering, as in metallurgy, young Ph.D.'s are not uncommon. There is a place for them in industry. Why this seeming contradiction? Are there several branches of engineering that are more scholarly than others, or have those industries employing certain kinds of engineers not appreciated the special graduate training, or is it possible that the kind and manner of graduate study common in the past has not fitted certain kinds of engineers for their profession?

It appears that in graduate study we in engineering have slavishly followed the older modes. Certain fields of metallurgy, following closely the sciences of physics and chemistry, may develop advanced study and research through classroom and laboratory methods. Advanced study of this kind becomes scientific rather than engineering in character. In the mining field, I believe that a graduate research in (for example) roof control can involve as scholarly a study as in any field of learning. Unfortunately, the laboratory here must be the mine itself and we of the classroom and university laboratory have not yet learned how to appraise or appreciate research work not done in orthodox surroundings. Following the examples just given, we can visualize research work in mechanics, hydraulics, chemical engineering, metallurgy, heating and ventilating and many other engineering fields that can well be carried on in the college laboratories and by standard methods. At the same time we can visualize a host of electrical engineering studies and research whose proper setting is the research laboratories of some large electrical industry, of design problems so specialized that the average college professor could hardly hope to instruct in them. In the iron and steel plants themselves I find the highest type of engineering research in progress in a variety of fields. What mechanical and combustion engineers have done in the field of power plants in the past ten years seems like miracles. All of this is grand engineering research, but hardly possible in the often times set and sterile college laboratory. Some time ago two industrial engineers finished a beautiful research on the delivery systems of city department stores; a civil engineer developed, down at the harbor, a new type of caisson. These achievements are engineering research of the highest order, as worthy of engineering college recognition as though they had been carried out in the college laboratories. I am of the view that every new engineering job wherever performed demands some of that peculiar thing called engineering research. Altogether, it seems clear that college laboratories in engineering have lost their leadership in research to the laboratories and other facilities of the large industries.

The foregoing indicates that we of the engineering colleges need not necessarily follow the older paths in recognizing and encouraging scholarly attainment. I suggest that in planning future graduate work in engineering we consider the following:

(*a*) Young graduates having the Bachelor's degree, before taking up formal graduate studies, should be encouraged to secure from one to three years of practical work, as a minimum, in the industries connected with engineering.

(*b*) Formal classroom work in graduate courses should be discouraged. Guidance of the student rather than instruction should be emphasized. If possible at least one third of his study should be in fields outside of engineering.

(*c*) We need a new vision of the variety, kind and place of graduate engineering research work. I see nothing sacred about a university laboratory. They are generally excellent for undergraduate instruction, but often too set and exact to carry on research on a graduate level. At one engineering school, there are graduate students registered who are employed by industries or by neighboring research laboratories. The research or investigation being carried out by the student in his every day work, becomes with proper safeguards his research project for his advanced degree. Never before have I seen such a wealth of mature high grade graduate engineering research results as are produced under this plan. In engineering and in mining education, let us get away from the notion that educational maturity is to be found only in the classroom and college laboratory.

(*d*) Years ago the so-called professional degree in engineering was adopted by many colleges. The Bachelor of Science graduate in engineering, after a term of years of acceptable practical experience, was awarded a professional degree, as Mechanical Engineer, on the presentation of an acceptable thesis. Lately, this degree has fallen somewhat into disfavor. If you are willing to concede that engineering is a particular kind of education, flowering best in originality of doing and in constructive practice, then the professional degree has a continuing place. The trouble is that we have through the years lowered the attainments necessary for the degree and made it a rather common thing.

(*e*) In engineering graduate work, let us, for certain branches of the profession, build on the knowledge that ours is primarily a profession of creation and accomplishment and not a mass of booklearning. I would like to forget the rules

and regulations of non-engineering graduate schools. I would allow a student to register for course A, even though he lived and worked a hundred miles from the campus. He would be an independent worker in the course; when he got into trouble he could write me, or drop in and talk with me. When he was ready to take an examination in the work, I would give it to him. Likewise, if a young engineer wanted to register for thesis in the design or plant work he is carrying on in his everyday position that would be acceptable to me. Most of the work would be carried out under his superior at the plant, but in the end, I would approve or reject his work as a thesis. That superior officer becomes really a highly specialized member of my faculty, second to none. The whole point is, that I want proof that the student has done and is capable of doing scholarly and original work and not when and where he has done it.

(*f*) I admit and recognize the invaluable graduate engineering work done in university laboratories and classrooms under regular methods; my plea is, however, that we recognize in engineering, the validity of our world wide work as a scholarly contribution to world progress. Engineering, above all other fields of learning can combine scholarly work outside the university walls with graduate work within.

ENGLISH NOTES

DEVOTED TO THE INTERESTS
OF TEACHERS OF ENGLISH
IN ENGINEERING SCHOOLS

J. L. VAUGHAN, EDITOR

THE IMPORTANCE OF ENGLISH TO THE ENGINEER IN INDUSTRY

C. F. KETTERING,

General Motors Corp., Detroit

A man's English is an index to his mind. A paper or report that is clearly and precisely written indicates sound reasoning and reliable results. An obscure, poorly written manuscript may disclose illogical and muddled thinking.

Success in engineering and research depends as much upon the ability to present an idea convincingly as it does upon the ability to perform calculations or experiments. You may perform the most miraculous experiment in the laboratory, yet you have not contributed anything to the advancement of knowledge until you have transmitted your results to others. It is only by speech and writing that the discoveries made in the laboratories are made useful. Scientific men too often look upon writing reports or making talks as an irksome part of their job and do as little of it as possible. Engineering work is not finished until the results are clearly recorded and presented to others.

The everyday use of English by the engineer is to write technical reports on his work for presentation to other engineers or to the management. These reports must present the results of his investigation in an accurate and orderly manner to those immediately interested in the work, and also to acquaint executives with the progress being made on the subject. After years of trying different methods of preparing technical reports, we have developed a procedure which makes it possible for everyone interested in the work to get the information he is after. On the first page, we start with a short foreword which explains, in general terms, the subject and reasons for the investigation. The second page contains the conclusions; concise and to the point. For the busy engineer or executive, the whole story is on the first two pages.

The remainder of the report contains a complete history of the development for the men who may be interested in the details of the project.

But in a larger sense, the engineer has an opportunity to use English in furthering the general understanding of the economic forces at work in our civilization. One reason why scientific work is publically discredited and blamed for economic difficulties is because it is not understood by the average man. Science and engineering needs interpreters to translate its findings into terminology understandable to all. One of the greatest problems in engineering and in science is to take a few days off and try to make plain to many people, the things we know so well. In other words, we need to get information, technical and otherwise, to flow down through to the public, because they are hungry to read and learn about the technical world. It is the job of the engineer or scientist, who has the technical background, to interpret the technical facts upon which modern civilization is based into language which everyone can understand.

The engineer who learns to master English and use it in these two important ways will do most to advance his chosen profession. He will be able to present his own investigations to his fellow engineers. More important still, he will be able to gain the understanding of our people who are interested in technical subjects, yet need them explained in simple language.

Editor's Note: The editor wishes to thank the teachers of English who supplied information for this directory. He is especially indebted to Professor Alvin M. Fountain whose interest and assistance made the following list possible.

TEACHERS OF ENGLISH OF SPECIALIZED TYPES FOR ENGINEERS

Abbott, John Paul, A. & M. College of Texas.
Ajax, Fred W., Ga. School of Tech.
Ayers, Joseph A., Univ. of Louisville.
Baker, Ray Palmer, Rensselaer.
Barley, J. W., Mo. School of Mines.
Bartlett, H. R., Mass. Inst. Tech.
Beckman, Richard W., Iowa State College.
Birk, N. B., Tufts College.
Birk, W. Otto, Univ. of Colorado.
Bloxsome, John L., Rose Poly. Inst.
Brewer, W. F., Mont. State College.
Buchan, A. M., Wash. Univ. St. Louis.
Butler, L. C., N. M. School of Mines.
Camp, T. W., Texas Tech. College.
Campbell, W. S., Univ. Okla.
Church, George F., Okla. A. & M. College.
Clark, George H., Queen's Univ.
Cloney, William T., Northeastern Univ.
Coie, J. S., State College of Wash.
Coombs, Z., Worcester Poly. Inst.
Crawford, Jack R., Yale Univ.
Creek, H. L., Purdue Univ.
Crouch, William G., Univ. Pittsburgh.
Cudworth, J. R., Univ. Alabama.
Cullihan, J. P., Kansas State College.
Cumberland, Robert, Cooper Union.
Daniel, D. W., Clemson College.
Davidson, D., Vanderbilt Univ.
Davis, L. E., Purdue Univ.
DeLaBarre, C. F., Va. Poly. Inst.
DeVries, P. H., Mich. State College.
Doak, Henry A., Univ. of N. D.
Drach, H. E., Univ. of Cincinnati.
Dumble, Wilson R., Ohio State Univ.
Dye, W. S., Pa. State College.
Eagleston, H., Calif. Inst. of Tech.
Farquhar, E. F., Univ. of Kentucky.
Fassett, F. G., Mass. Inst. Tech.
Fountain, Alvin M., N. C. State College.

French, R. DeL., McGill Univ.
Frommelt, H. A., Marquette Univ.
Giesy, Paul M., Newark College of Eng.
Gott, C., Tufts College.
Graves, H. F., Pa. State College.
Guthrie, Ledru O., Univ. of Minn.
Hall, Amy V., Univ. of Wash.
Harbarger, Sada, Ohio State Univ.
Harrison, T. P., N. C. State College.
Haviland, T. P., Towne Sci. School.
Hendricks, Walter, Armour Inst. Tech.
Hess, E. D., Ala. Poly. Inst.
Hinkle, George, Stanford Univ.
Hofford, W. M., R. I. State College.
Holmes, F. W., Northeastern Univ.
Howell, A. C., Univ. of N. C.
Hudson, Hoyt H., Princeton Univ.
Jones, W. Paul, Iowa State College.
Judy, C. K., Calif. Inst. Tech.
Knickerbocker, K. L., R. I. State College.
Kunn, Kenneth, N. D., Agri. College.
Lassalle, L. J., La. State Univ.
Lilly, S. B., Swarthmore College.
Lowe, Lewis R., Case School of Appl. Sci.
McDonald, Philip B., New York Univ.
McKillop, Alan D., Rice Inst.
McPherson, Malcolm, Univ. New Brunswick.
Melvin, H. W., Northeastern Univ.
Mitchell, C. H., Univ. of Toronto.
Morgan, Jesse R., Colo. School of Mines.
Morgan, Stewart S., A. & M. College of Texas.
Nugent, Homer H., Rensselaer.
O'Bannon, L. S., Univ. of Kentucky.
Pattison, S. F., Univ. of Ariz.
Park, Clyde, Univ. of Cincinnati.
Pearson, H. G., Mass. Inst. Tech.
Peck, Helen E., R. I. State College.
Peet, T. B., Ala. Poly. Inst.
Pepper, L. R., Univ. of Missouri.
Perry, William G., Ga. School Tech.
Peterson, S. H., Ore. Agri. College.
Phy, C. Wesley, Lehigh Univ.
Raw, Ruth M., Univ. of Akron.
Raymond, Fred N., Univ. of Kansas.
Richardson, C. S., Univ. of Maryland.
Richardson, H. C., Univ. of Minn.
Rockey, N. W., Kansas State College.
Roop, Joseph E., Ala. Poly. Inst.
Rose, L. A., Mich. College of M. & T.
Rowe, G. M., S. D. School of Mines.
Rutland, J. R., Ala. Poly. Inst.
Scammon, W. F., Univ. of Maine.
Scott, Duncan, Jr., N. M. State College.
Scott, John Hubert, State Univ. of Iowa.
Sibley, Robert P., Cornell Univ.
Smock, G. E., S. D. State College.
Stevenson, B. V., Univ. of Toledo.
Stimmel, Lester H., Colo. State College.
Sturmer, Anna M., Kansas State College.
Strover, Carl G., Univ. of Hawaii.
Summey, George, A. & M. College of Texas.
Sypherd, W. O., Univ. of Delaware.
Thomas, M. B., Univ. of Alabama.
Thompson, Karl O., Case School of Apl. Sci.
Thornton, J. E., Univ. of Michigan.
Townsend, Atwood, New York Univ.
Tucker, Marian, Poly. Inst. of Brooklyn.
Twitchell, H., Univ. of Cincinnati.
Van Hagen, L., Univ. of Wisconsin.
Vaughan, J. L., Univ. of Virginia.
Watt, Homer A., New York Univ.
Webster, Robert G., Univ. of N. H.
Westfall, Alfred, Colo. Agri. College.
Weston, A. J., Stevens Inst. of Tech.
Weygandt, Cornelius, Moore School of E. E.
Wheeler, Paul M., Johns Hopkins Univ.
White, Owen S., Univ. of Porto Rico.
White, R. C., Tufts College.
Whitney, Norman J., Syracuse Univ.
Wollermann, I. D., Univ. of Cincinnati.
Wood, Ella Lucille, Mich. College of M. & T.
Wright, W. J. T., Univ. of Toronto.
Wykoff, G. S., Purdue Univ.

CIVIL ENGINEERING DIVISION

L. E. GRINTER, *Chairman*
H. C. BIRD
F. T. MAVIS

K. C. REYNOLDS, *Secretary*
H. E. BABBITT
HALE SUTHERLAND

THE PROGRAM AT BOSTON

BY L. E. GRINTER

Chairman 1936–1937, Texas A. and M. College

To those of you whose interest will be in attending the Cambridge meeting rather than in arranging the program, this message may seem premature. However, several months of effort are involved in making the arrangements for a well rounded program such as, quite naturally, we hope to have. Objectives must be decided upon, speakers must be found, papers must be written, chairmen and toastmasters must be selected, and, finally, local arrangements must be made for presenting the program adequately.

It is not to be expected that any one man or any small group of men would know all the interesting speakers or all of those who would have a valuable idea to present at the meeting. Your aid is, therefore, solicited in suggesting speakers and topics for papers. Call our attention to your associates who speak entertainingly or who are particularly fitted to speak authoritatively on any subject pertaining to the teaching of civil engineering. Address your communication to the Chairman, the Secretary, or to any Committee Chairman of the division as listed in the December issue of the *C. E. Bulletin*. There is no reason for you to be embarrassed in offering your own services on the program. We will appreciate all such suggestions.

There is some consideration being given to the idea of centering the program at Cambridge around the teaching of mechanics, that is, around general mechanics, strength of materials, the mathematical theory of elasticity, hydrodynamics, soils mechanics, and advanced structural mechanics. Whether this program would appeal to you or whether you have a better suggestion to offer, those responsible for arranging the program would appreciate greatly any proposals that you wish to make. And do not forget to mention your suggestions for speakers and for topics to be discussed, including your own willingness to serve the division.

The T-SQUARE PAGE

DEVOTED TO THE INTERESTS OF THE DIVISION OF ENGINEERING DRAWING

FRANK A. HEACOCK, EDITOR

NATIONAL DRAWING COMPETITION

General Regulations for School Year, 1936–1937

AUSPICES OF THE DRAWING DIVISION
SOCIETY FOR THE PROMOTION OF ENGINEERING EDUCATION

CARL L. SVENSEN, Box 933 Lubbock, Texas, Chairman of Committee

1. Work is limited to first year (or equivalent) drawing courses. Students in advanced courses or who have been professionally employed as draftsmen should not be entered.

2. An engineering drawing department may submit one drawing only in each class: AP, AT, AI, BP, BT, BI, C, D, and E (does not refer to school classes).

3. Each submitted drawing must be accompanied by a statement concerning the following information:

a. The competition class in which the drawing is to be entered.

b. The name, address, and institution of the drawing teacher.

c. The number and length of lecture or class periods, the number and length of drawing room periods, and the number of "home work" periods which were available to the student prior to and including the time spent on the submitted drawing.

d. The number of units, semester hours credit or yearly credit, of mechanical drawing earned by the student competitor before entering college.

e. The name and address of the student whose drawing is submitted.

4. The problems and special specifications supplementing these general rules will be furnished schools desiring to enter contestants. Application should be made to the Chairman of the Competition Committee, Carl L. Svensen, Box 933, Lubbock, Texas, who will supply the necessary problem specifications and identification numbers for the contestants. Specifications will be furnished contest-

ing students through their instructors. The school's best drawing in each class will be entered in the National Competition. An elimination contest in each school is suggested as one means of selecting the best drawing.

The Classes in General

In all cases the drawing is to be made from the problem project supplied by the Drawing Competition Committee and in accord with the specifications and regulations which apply to the particular classification.

Class AP.—Required: A pencil drawing made with instruments embodying orthographic shape description. Choice and treatment of views, as well as execution are a part of the problem.

Class AT.—Same as Class AP except that a pencil tracing (accompanied by the pencil drawing) is required.

Class AI.—Same as Class AP except that an inked tracing (accompanied by the pencil drawing) is required.

Class BP.—Same as Class AP except, required: A pencil drawing made with instruments, including both an orthographic shape description and size specification. Choice and treatment of views, execution, dimensioning, etc., are part of the problem.

Class BT.—Same as Class BP except that a pencil tracing (accompanied by the pencil drawing) is required.

Class BI.—Same as Class BP except that an inked tracing (accompanied by the pencil drawing) is required.

Class C.—Required: A complete working (shop) drawing submitted in the form of an inked tracing accompanied by the pencil drawing. Choice and treatment of views, dimensioning, etc., are a part of the problem.

Class D.—Required: A freehand pictorial sketch. Choice of position, method of representation, execution, etc., are a part of the problem.

Class E.—Required: Lettering in pencil and lettering in ink from written copy. Arrangement, form and proportion of letters, execution, etc., are a part of the problem.

Judging

First and second places will be awarded in each class except that no awards will be made for any class in which there are not at least five entries.

Theory, practice, technique, and student judgment shall constitute the basis for judging all drawings.

The judges shall be three in number selected by the Chairman of the Division of Engineering Drawing. The Chairman of the National Competition Committee shall be, ex-officio, a non-voting member of the judging committee.

COLLEGE NOTES

Massachusetts Institute of Technology.—An electrostatic generator capable of producing penetrating short-wave x-rays at a potential of 1,000,000 volts for medical research and the treatment of malignant disease is nearing completion at the Collis P. Huntington Memorial Hospital in Boston. Announcement of this new tool of medical science, which was designed by Professor John G. Trump of the Massachusetts Institute of Technology and built under his supervision, was made by Dr. Richard Dresser of the Huntington Memorial Hospital at the annual meeting of the American Roentgen Society at Cleveland.

The new generator, which is expected to be ready for operation this winter, possesses two distinct advantages over existing equipment. First, it will make possible the treatment of deep-seated malignancy because high-voltage x-rays have greater penetrability than low-voltage rays. It is expected that many types of malignant disease which cannot be treated effectively with equipment now in use, will yield to the more penetrating short-wave rays produced by the new machine.

A second advantage is indicated by accumulated evidence that high-voltage x-rays are more specific in their action on diseased tissue than the relatively low-voltage rays now in general use. In this respect the effects of high-voltage rays are similar to those of the gamma rays of radium. The new x-ray generator, however, will be capable of producing a greater intensity of these rays than the combined output of all the available radium in the world.

The 1,000,000 volt generator is an outgrowth of the high-voltage research program of the Massachusetts Institute of Technology, and is similar in principle to Technology's huge high-voltage generator at South Dartmouth, Mass., developed by Dr. Robert J. Van de Graaff and his associates. Its construction is in charge of Frank Scholz of the Huntington Hospital staff.

The x-ray tube is made up of 20 porcelain sections of about 12 inches diameter, totaling 10 feet in length. Diaphrams are provided between sections to focus the high-speed electron stream in its passage from the upper end of the tube to the target, and also to break up the total potential which must be insulated between the two ends of the tube. The base of the porcelain assembly is supported by a steel cylinder, which projects through the floor of the generator room into the treatment room, the arrangement being

continuously evacuated by the high-speed pumping system. The filament assembly is located on the upper end of the porcelain column and is so arranged that replacement of a filament will involve only a short interruption in service.

A demountable, water-cooled target of gold upon which the high-speed electrons impinge is attached to the bottom of the steel cylinder. Both cylinder and target are at ground potential and are surrounded by a thick armor of lead for shielding against direct radiation. The beam of penetrating x-rays emerges through a port in the lead shielding in the direction of the patient being treated.

The Aircraft Instrument Section and the Internal Combustion Engine Laboratory are carrying out two coöperative research projects which should produce useful results in the near future.

The first project is the construction of a mechanical integrator to study transient and steady state motion in coupled systems. The apparatus consists of a heavy frame to support two or more simple torsional systems with adjustable moments of inertia. These systems are connected by variable elastic and friction elements. The essential motions are recorded by means of pencils marking on a continuously moving strip of paper. The actual work of design and construction is being done by J. B. Kendrick, J. L. Witherstine and Edward Gugger. Professor E. S. Taylor will apply the new equipment to aircraft engine problems. It will also be used by Professor C. S. Draper in connection with aircraft instrument developments.

The second coöperative project is the development of apparatus to make simultaneous records of the pressure waves at two points inside the cylinder of an internal combustion engine. The frequencies involved range from below ten to over thirty thousand cycles per second so that cathode ray oscillographs with special amplifiers are required. The apparatus uses two commercial cathode ray tubes with an optical system for producing adjacent traces on motion picture film.

Michigan College of Mining and Technology.—The usual increase in new students registered for the winter term brings the total enrollment to 580, third largest enrollment in the history of the college.

Recent promotions in academic ranking made by the Board of Control are now in effect. James Fisher, head of the department of mathematics and physics, is new dean of the faculty. Other changes are: Bart Park of the chemistry department and A. P. Young and H. W. Risteen of the mechanical engineering depart-

ment, promoted to associate professors, and Walter Keck of the metallurgy department promoted to assistant professor.

Two new clubs have been organized among the students—a chapter of the American Society for Metals, which is under the faculty sponsorship of Instructors Harold Walker and Paul Beck of the metallurgy department, and a Forestry club, sponsored by R. B. Miller of the forestry department.

The annual Winter Carnival, sponsored by Blue Key society, and the bi-annual Engineering Show, will be held on the campus at Houghton in January and April respectively.

Missouri School of Mines and Metallurgy.—H. L. Dunlap resigned his position as Professor of Chemical Engineering, which work he has taught for the past seventeen years, to accept a position as Professor of Chemical Engineering at the Ohio University in Athens. Dr. Dunlap was succeeded by Frank H. Conrad, who received his Doctor of Philosophy degree from the University of Washington in 1934 and has had both industrial and teaching experience.

George R. Dean retired as Professor of Mathematics after having served the School for thirty-eight years in this capacity.

E. G. Harris, Professor of Civil Engineering, has also retired after a service of forty-five years.

Other retirements are those of R. F. Ratliff as Associate Professor of Physics, and S. P. Bradley as Assistant Professor of English.

David J. Peery has been appointed instructor in Civil Engineering. Peery received his B.S. degree from the School of Mines in 1934 and a Master's degree from the University of Michigan on a Tau Beta Pi scholarship in 1935. He has had practical experience in construction work with the Missouri State Highway Department since leaving the University of Michigan.

The School was inspected on November 9, 10, and 11 by the Accrediting Committee of the Engineering Council for Professional Development under the chairmanship of Dean A. A. Potter of Purdue University.

The enrollment at the School of Mines this year shows a 20% increase over last year, the largest yearly increase since the return of the students following the World War.

The pick-up in business activities is reflected in the demands for junior engineers. All graduates, of the School of Mines, so far as is known by the administrative office, have employment at this time.

Rensselaer Polytechnic Institute.—Grant K. Palsgrove, professor of hydraulic engineering has been named vice-chairman for the middle Atlantic section of the Society.

LeRoy W. Clark of the civil engineering department has been commissioned a Lieutenant Commander in the Naval Reserve of the U. S. Navy, and has been assigned to the Civil Engineering Corps for special service. For years many graduates of the U. S. Naval Academy at Annapolis have been sent to Rensselaer Polytechnic Institute for post-graduate training.

Edward J. Kilcawley has been elected president of the Rensselaer County Chapter of the Professional Engineers Society.

For the first time in its history of more than one hundred years, the faculty has approved a spring recess. The time from classes will be from March 19 to March 29, and is given primarily so that students may visit industries connected with the work of their departments. A spring vacation had been sought for years by student bodies at Rensselaer.

Two members of the faculty, Elbert F. Corwin and Kenneth H. White, who teach meteorology, recently made a study of weather conditions in the Adirondacks. One result was the explosion of a widely held belief that Owl's Head was "The Ice Box" of the state. Corwin and White found other places just as cold, some colder. They said they believed Owl's Head had made the nation's headlines for many years simply because it told the world how cold it was there.

Yale University.—Hardy Cross, one of the country's best known structural engineers, has been appointed Professor of Civil Engineering. Professor Cross, who has also been appointed Chairman of the Department of Civil Engineering, comes to Yale from the University of Illinois, where he has been Professor of Structural Engineering for the last fifteen years. The author of several books and numerous papers in civil engineering, he is particularly known for developments in rigid frame analysis.

Professor Cross is a graduate of Hampden-Sydney College and the Massachusetts Institute of Technology. In 1911 he received the degree of master of science in civil engineering from Harvard and in 1934 the honorary degree of doctor of science from Hampden-Sydney. After some years of railroad engineering experience he served for seven years on the faculty of Brown University. Three years of general structural engineering practice were followd by his appointment to the University of Illinois in 1921. The appointment takes effect next fall.

SECTIONS AND BRANCHES

At the last meeting of the **North Carolina State College Branch** of the S. P. E. E. the following officers were elected for the current school year:

President, H. E. Scatterfield, Associate Professor of Mechanical Engineering.

Secretary, C. R. Bramer, Assistant Professor of Civil Engineering.

C. R. BRAMER,
Secretary

The annual meeting of the **Southeastern Section** will be held at the University of Florida, Gainesville, April 2 and 3, 1937.

NEWTON C. EBAUGH,
Secretary

BOOK REVIEWS

Analytic Geometry. By PALMER H. GRAHAM, F. WALLACE JOHN, AND HOLLIS R. COOLEY. N. Y., Prentice Hall, Inc., 1936. xx + 294 pp. $2.35.

In writing this text the authors have disclaimed any attempt at novelty. They have tried rather "to present the material and arrange the explanation in a manner that will be easily grasped by the average student and that will insure a highly flexible text in the hands of the instructor." The material is divided into fifteen chapters. The first discusses the two most widely used systems of coördinates, rectangular and polar, together with simple applications. The concepts of graph, directed line segment, distance between two points, angle of inclination, slope, parallelism, perpendicularity, angle between one line and another, point of division of a line segment are introduced. Then follow chapters on the straight line, the circle, the parabola, the ellipse, the hyperbola, transformation of coördinates and the general equation of the second degree, transcendental equations, general locus problems, the conic sections, empirical equations, solid analytic geometry (introduction), the plane (in space), the straight line (in space) and surfaces.

Determinants are freely used; and the limit process is introduced in determining the equation of a tangent to a conic. Both of these are good features. Interesting historical notes appear from time to time. The reason given on page 34 for the term "normal" as applied to Hesse's form for the equation of a straight line is believed by the reviewer to be incorrect.

This is an excellent textbook and should win the approval of teachers of analytic geometry.

College Algebra. By HOBART C. CARTER. N. Y., Prentice Hall, Inc., 1936. ix + 234 pp. 8°. $1.50.

An analysis of this book reveals that when deductions are made for the exercises, answers, tables and index about a hundred pages remain for the discussion of the topics. Much of the discussion itself is devoted to the statement and solution of illustrative examples, about 70 in all. Moreover, the pages are small, and the type large. The topics considered are in order: the number system of algebra, factoring, fractions, exponents and radicals, functions and equations (the definitions), graphical representation,

linear functions, quadratic functions, algebraic functions (polynomial and fractional), the logarithmic function, the exponential function, variation, permutations and combinations, the binomial formula, probability, progressions, mathematical induction, determinants, frequency distributions, investments, systems of numeration.

In spite of the paucity of discussion and the extensive range of material covered the explanations are surprisingly adequate. This is partly due to the author's attempt to be both general and concise. It is also due in no small measure to an abundant use of illustrative worked examples. The book combines to some extent the features of a syllabus and an exercise book.

The arrangement of exercises is noteworthy. We quote from the preface: "Three complete sets of exercises A, B, and C are given at the end of each section. Any one of these sets contains all the fundamental ideas of the section, and the teacher is not confronted with the problem of selecting the necessary examples from a large group. An additional set of exercises, D, is designed for the honor students. In addition a mastery test is given at the end of each chapter, and general review exercises are given at the end of the text."

Interesting historical items occur frequently as footnotes.

We believe that this book is a worthy addition to texts in the field of elementary college algebra.

A. E. STANILAND

PRELIMINARY ANNOUNCEMENT OF 1937 SUMMER SCHOOL ON ECONOMICS

A summer session on Economics of Engineering will be held at the Stevens Engineering Camp, Johnsonburg, N. J., from June 20 to 27, 1937. This will be the first of the economics summer schools to be held in proximity to the annual meeting of the Society; as it immediately precedes the Cambridge meeting it will be convenient for members from other sections of the country to attend both on the same trip.

The initiative for this 1937 session at Johnsonburg came from some of the members who attended the very successful 1936 session there. The atmosphere of camp proved so favorable to those informal discussions that help to make such a meeting worth while, and the combination of the S. P. E. E. group, 39 in number, with an approximately equal number of engineers from practice, seemed so satisfactory that many of us felt that we would like to repeat the experience in 1937 when we could readily combine the attendance at Johnsonburg and Cambridge. The following comment from Professor McMullan of Drexel Institute was typical of the opinion of the members of the 1936 session:

"I do not believe that I have ever spent a week that was so crowded with important things to do and so free from clashes in personalities and from routines. I come back to my work feeling refreshed in both body and spirit, and certainly with a more complete understanding of what the engineer is supposed to know about economics."

It is not contemplated that such sessions be held annually, but it was thought that in this relatively new and somewhat controversial field of engineering instruction sessions may well be held every three or four years in the neighborhood of the Annual Meeting, and that 1937 seemed like a good time to embark on such a program.

An invitation from Stevens Institute to the Society for the Promotion of Engineering Education to hold an Economics summer school at Johnsonburg in 1937 has been accepted by the Executive Committee of the Society. The Society's Committee on Engineering Economy will coöperate with the Stevens Institute authorities in arranging the program. The details of the arrangements will be announced in subsequent issues of the JOURNAL.

EUGENE L. GRANT,
Chairman, Committee on Engineering Economy.

TO INSTITUTIONS EXPECTING TO INVITE THE S. P. E. E. CONVENTIONS

Institutions expecting to invite the S. P. E. E. Convention within the next three years should indicate their intention to do so to the Secretary at an early date in order that the time and place of our convention can be adjusted to arrangements of other national engineering societies to avoid conflicts and to promote the convenience of members who may wish to attend the various June meetings.

Such notice should include information covering the following items:

1. Year for which the invitation will be extended.
2. Days in June of that year most convenient to the institution which expects to be host. Give dates of your commencement and of opening summer session for that year.
3. Capacity of hotels in city. Capacity of college dormitories available for the convention.
4. Membership of S. P. E. E. within 200-mile radius of the institution.
5. Advantages and supporting statements.

By order of the Committee on Relations with Other Engineering Societies.

NOTE: Council authorized the policy of fixing the place of the annual meeting two years in advance so as to avoid undesirable conflicts with conventions of national engineering societies, and also in so far as practicable to have our convention come in sections of the country which would make it convenient for our members to attend one of the national conventions also. The Committee on Relations with Other Engineering Societies acts in an advisory capacity to the Council in recommending the place of the annual meeting.

F. L. BISHOP,
Editor.

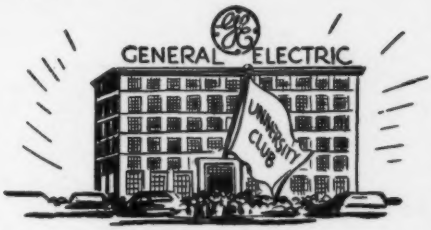
G-E *Campus News*

LIGHTNING STRIKES TWICE

LIGHTNING may strike not only twice but a dozen times in the same place over the same path within one second's time. This is one of the unusual facts that Karl B. McEachron, Research Engineer of General Electric's High-voltage Laboratory, has found out about lightning.

Even more unusual is the new theory that the brilliant lightning flash one observes during a storm is not a bolt from the sky, but a union of a cloud streamer with a similar one from the earth. The action of the air currents and of the falling drops of water separates the charges in the cloud. When the voltage in the cloud reaches a certain value, a streamer starts towards the earth, traveling in jumps at about one-tenth the speed of light. When this streamer is a few hundred feet away, streamers from four to eight feet long begin to form on the surface of the earth. When the streamer from the clouds unites with one from the earth, the flash of lightning occurs. The pressure generated during the passage of current makes the thunder.

General Electric conducts research in lightning so that its engineers can design transmission lines and protective equipment which will insure better continuity of service.



UNIVERSITY CLUB

DAVE PACKARD of Stanford and Otto Schwartz of Columbia played against each other in the Rose Bowl game of 1934, but now they are working side by side in the Schenectady Works of the General Electric Company. This seems unusual until it is pointed out that in the General Electric organization is one of the largest and most cosmopolitan university clubs in the world. Approximately 4500 college graduates, representing 237 American universities, colleges, and technical schools, are employed by the Company. In addition, there are 198 graduates from universities in 22 foreign countries.

Ten educational institutions have contributed more than 100 graduates each to the General Electric family. They are: Cornell, Iowa State, M.I.T., Penn. State, Pratt Institute, Purdue, Union College, U. of Colorado, U. of Michigan, and Yale. Fifteen other schools have provided more than 50 graduates each. They are: Case School, Georgia Tech., Kansas State, U. of Maine, U. of Minnesota, Ohio State, R.P.I., Syracuse, U. of California, U. of Illinois, U. of Kansas, U. of Nebraska, U. of Wisconsin, V.P.I., and Worcester Polytechnic.

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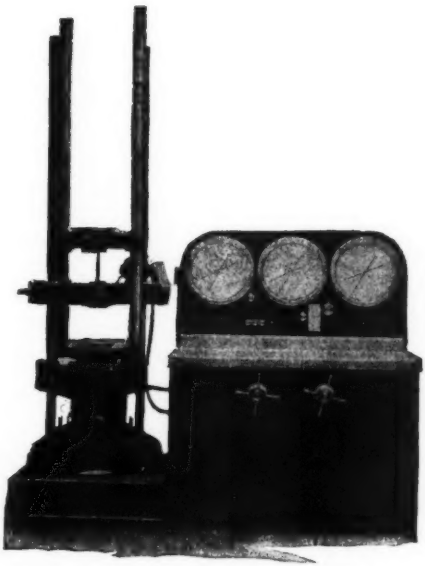

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